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Philosophical and Educational Perspectives on Engineering and Technological Literacy, II

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Philosophical and Educational Perspectives on Engineering and Technological Literacy, 2

Contents

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Editorial

Unknown to each other two groups of engineers and engineering educators began to consider aspects of philosophy and engineering. One held a workshop of engineers and philosophers- “Engineering meets Philosophy” at Delft University and the other held a special session at the annual Frontiers in Education Conference on engineering education and philosophy. Since then the former has held a biannual workshop that have resulted in two impressive publications. The other continued its discussions through FIE and ASEE conferences. There are now regular sessions on philosophy and engineering education at the annual FIE conferences.

It was argued that all engineering educators should reflect on their personal philosophies of engineering education and pedagogy. For this to happen, however, there would need to be a more permanent home for philosophy within ASEE. The Technological Literacy Division of ASEE presented a substantial case for embracing philosophy and at the 2013 Atlanta meeting it was proposed that the Division should change its name and rationale to embrace both philosophy and engineering literacy. Subsequently these proposals were adopted by ASEE and the division is now the technological and Engineering Literacy and Philosophy of Engineering Division (TELPhE). It was made clear that it would collaborate with its cognate divisions to bring about the acceptance of the view that all engineering educators should have an operational understanding of their own philosophies and how these impacted on policy.

At the same time the Division approved the development of a hand book and expressed the hope that a bibliography on engineering education and philosophy that been prepared for a one day workshop at FIE 2011 would be revised and published.

So far one peer reviewed handbook has been published with papers financed by the participating authors and other supporting sponsors. For the convenience of the reader the contents of the first handbook have been listed below the contents of this volume. We have changed the format of this volume to reduce costs. We hope that the reader will find it equally presentable.

This second hand book has also been peer reviewed and financed by the authors and a third is in production. However, it only partially meets the needs of the division and those working in cognate areas. There are major issues about the content and method of teaching technological and engineering literacy that need to be debated for which a vehicle for publication is required. Because the Divisions officers wish to meet that need we have changed the title of this second handbook to include the term ‘educational’ and hope it will encourage members of the division and those working in cognate fields to consider contributing to this publication and helping it to develop.

This issue focuses on pragmatism and one of its exponent s John Dewey and two relatively unknown twentieth century philosophers. The first is the twentieth century Jesuit philosopher Bernard Lonergan. The second is the Scottish Philosopher John Macmurray. The reader will find that engineering education has much to learn from the work of these philosophers.

The third issue will also include further studies of the pragmatists and John Dewey and tackle the thorny issue of the aims of education. The second is the Scottish Philosopher John Macmurray.

Pragmatism, Practice, and Engineering

Russell Korte

Introduction

This essay explores a practical perspective of engineering work grounded in a Pragmatist philosophy and Practice theory. Essentially, Pragmatism focuses on the practical outcomes of what we think and do. It is about making a difference in the world that matters (Dewey, 1938; Peirce, 1878; Rescher, 2000; Talisse & Aikin, 2008). Practice theory frames and explains the activities that are continually performed, produced and reproduced through a dynamic entanglement of action, politics, communities, discourse, materials, tools, and human agents. These two related perspectives focus on the consequences of our ideas and the results of our work. Both perspectives have tremendous power to focus our inquiry, clarify our perceptions of the world, and organize our thinking.

The questions guiding this essay are: (1) How might one approach the nature of engineering work from a practical perspective? (2) What does it mean to practice engineering? This emphasis is less on the ideal or formal scientific intentions of engineering education and more on the nature and consequences of engineering practices in the workplace.

One of the unfortunate consequences of the fabulous rise of science over the past few centuries is the growing chasm between the views of scientific objectivity and human subjectivity. Pragmatism and Practice theory not only recognize the important effects of human interactions within societies, but also place human activity, with all of its subjectivity, center stage. Thus, theorizing is an important component of Pragmatism and its efficacy derives from the utility of its guidelines for action (Rescher, 2000). It is this focus on action and everyday experience that distinguishes the overall Pragmatist and Practice efforts to make sense of things.

Rather than pursuing idealist notions of what the world might be or ought to be like, Pragmatist philosophers focus on the "problems of everyday life in this messy world." The chief aim is for solving problems (Kaplan, 1961, p. 13). And arguably one of the important tasks of a Pragmatist worldview is to make sense of the profound effects of science and technology on human civilization. As a result, Pragmatism provides a workable system of ideas (a philosophy) for integrating the beliefs and values of our current milieu (Kaplan, 1961).

An aim of philosophical inquiry is to develop a more adequate understanding of the world for the purpose of developing more adequate practices in the world. Philosophical inquiry helps us make better choices (Rescher, 2001). Through philosophical inquiry, we attempt to describe how the world hangs together and how it works at levels beyond that which empirical science has explained. Despite the power of science to explain enormously complicated phenomena, there are things that science has not, or cannot explain, such as human meaning, purpose, reality, and truth (Rescher, 2001). A more practical and systematic understanding about how things work is important for grappling with the more intractable problems found in the world.

The next section briefly reviews a selection of important ideas of Pragmatism. This is followed by a selection of important ideas emerging as Practice theory. Pragmatism focuses on the consequences of or actions brought on by our system of ideas or beliefs. Practice theory is a collection of emerging theories about systematic actions, such as the work we do and why we do it the way we do. These brief and selective reviews lead to important implications for the work that engineers do.

Pragmatism

As a relatively recent development in the history of philosophy, Pragmatism encompasses a vast range of perspectives, ideas, and contradictions. Yet there are key ideas that differentiate Pragmatism from other philosophical perspectives and are useful to inform engineering practice. Three common areas of interest emphasized by Pragmatist philosophers are: (1) the focus on the practical consequences of action, (2) the primacy of community (social), and (3) the experiential grounding of problem solving (Bernstein, 2010).

The words "pragmatism", "practice", and "practical" derive from the Greek word for action (πραϒμα). And although the early authors of Pragmatism did not use the word Pragmatism to describe their work, the word eventually came to describe a distinctive new American view of the world (Bernstein, 2010).

Often considered the founder of Pragmatism, Charles Peirce (1878) proposed what became known as *The Pragmatist Maxim* stating that the courses of action suggested by an idea compose the sole meaning of that idea. It was actions and their entailing consequences, not ideals or principles that were foundational to the Pragmatist worldview. William James (1907/1995) extended this view to include not only the meaning of ideas, but also the notion of truth. He defined truth as *what is better for us to believe* rather than the classic notion that truth is *an accurate representation of reality* (Bernstein, 2010). This change in focus from abstract, ideal principles to practical consequences challenged the traditional ideas of the world and of reality—traditional ideas that are still strongly entrenched today.

Bernstein (2010) described Charles Peirce's development of a practical philosophy in the late 1800s as a reaction against the dominant Cartesian ideas that claimed we have the power of introspection and intuition to learn the truth independent of the external world; we have the power to think without signs (language), and we can conceive of what is incapable of being recognized, known, or distinguished. These idealist notions of understanding the world drove the early Pragmatists away from philosophies based on idealism and realism that claimed we could accurately and with certainty represent the real world. The rise of science and a focus on practice and practical effects fostered the development of pragmatist thinking.

In addition, Pragmatism rejected the Cartesian idea of objectivity and truth. The Cartesian Correspondence Theory of Truth claimed that there was a reality out there and any assertion of truth was justified to the degree that it corresponded to reality. For many simple assertions of the natural world this works very well. However, for the complex assertions regarding science, mathematics, history, or human and social phenomena the Correspondence Theory is untenable (Bernstein, 2010). Justifications of correspondence to reality rely on language, reason, and representations of reality that are prone to arbitrary factors of circumstance, power, and individual biases (Bernstein, 2010). To the Pragmatist, a more useful view of truth and objectivity comes out of an intersubjective (social or communal) justification. This aligns more with a Coherence Theory of Truth, which advocates a more consensual and situational explanation of truth. However, a Coherence Theory is not without criticism as an idealist perspective that eschews a mind-independent reality (Young, 2013).

Another common criticism of this intersubjective view is that it is relative, which criticizes the accommodation of any view of the truth. Yet the Pragmatists propose that rather than resorting to a simplistic view of relativism, it is better to base truth on the results achieved from collective inquiry and deep critical analysis. Out of a deep commitment to systematic inquiry we might reach an adequate understanding of reality that works and is therefore the best available truth (Bernstein, 2010). Truth is not something "out there" waiting to be discovered. It is what one constructs through inquiry. It emerges out of the careful, collective development of evidence or knowledge (Talisse & Aikin, 2008). The notion that truth is found in the practical outcomes of inquiry is controversial and challenged by others holding to a more idealist perspective. Yet James (1907/1995) countered that the concept of ideal truths is impractical and unrealistic—essentially, all we can really know comes from what we do in the process of inquiry and discovery. Systematic, collective inquiry is the best we can do to construct the best available truth. There is no delusion of or practical need for believing in an ultimate, certain Truth. Pragmatism views the notion of an ultimate Truth as a myth that we are better off ignoring.

Currently, Pragmatist philosophers tend to invoke a deflationary theory of truth that avoids the controversy with Idealism by not affording too much status to the concept of truth. The deflated notion of truth appeals to many modern Pragmatists as an assertion, along with commitments that what is asserted will be supported by evidence and stand up to its challenges, or be abandoned. The Pragmatist theory of truth is that truth is fallible and is less about metaphysics and more about epistemology or learning from inquiry (Talisse & Aikin, 2008).

The growing interest in the natural world and the notion that people are an integral part of the natural order of things led early Pragmatists away from the classical, theological perspectives of the world. The use of science as a means to inquire about the world came to be called Naturalism and was adopted as a foundational aspect of Pragmatism (Talisse & Aikin, 2008).

There were two major components of Naturalism: methodological and nomological. A Naturalistic methodology of inquiry emphasizes the scientific method that is self-correcting and relies on experiment, empirical evidence, and public scrutiny. A methodological assumption of Naturalism is that there is an underlying continuity between science and philosophy. If new evidence challenges existing scientific beliefs— new evidence can challenge existing philosophical beliefs as well (a condition known as *fallibilism*). A nomological view claims that the world is natural and conforms to natural laws independent of our beliefs of them. However, we can use our understanding of these laws and their effects on our perceptions to ascertain what the real world is like and how it works (Talisse & Aikin, 2008).

In addition, Pragmatic Naturalism contained a third component, *Humanism*, that is antireductionist in its goal of preserving and aligning scientific and philosophical work with the values and purposes of human beings. The humanist aspect of Pragmatic Naturalism rejects the reduction of values, aesthetics, and the social realm to the biology or chemistry of the human organism. Dewey's (1938) view of the 'spectator view of knowledge' was similar in its rejection of pursuing knowledge without attending to how it affects human lives.

There are problems with Pragmatic Naturalism. For example, integrating the nomological aspect of naturalism conflicts with a situational view emphasizing practical effects. Also, integrating humanism and naturalism poses difficulties when the goal of non-reductionism blocks the advancement of an inquiry, or when the scientific method used in the search for truth clashes with our evolutionary goals of survival or our humanistic values (Talisse & Aikin, 2008). These conflicting ideas are some of the lingering problems still to be worked out.

Regarding the Pragmatist approach to beliefs, Talisse and Aikin (2008) described beliefs to be those thoughts that are held to be true and discernable because they entail related actions or consequences. We act according to our beliefs. This is a functional view of beliefs aligned with the Pragmatic notion that actions and consequences provide the sole meaning of our beliefs (Talisse & Aikin, 2008). Thus, it is the consequences of our ideas that are important, not the ideas alone.

Common Pragmatic views hold that there are many views (or vocabularies) of the world (i.e., there are multiple metaphysics) each being more or less fit for interacting with the world (Talisse & Aikin, 2008). Thus the utility of a metaphysical perspective derives from its goodness of fit in a particular situation—and this measure can only be applied from within the stated view or vocabulary. Multiple views can easily conflict with each other. Pragmatists argue that criticizing one worldview by invoking the belief system of a rival worldview is useless, because it does not lead to useful action. To evaluate a worldview compared to an alternative worldview requires developing a higher-level worldview (a third vocabulary) that encompasses the two rival worldviews, along with a new set of criteria and measures to evaluate the utility of either one (Talisse & Aikin, 2008). Essentially, this argument states that one needs to find an overarching "common ground" encompassing both rival views before useful action can be taken to work out or criticize the differences. Rigidly holding to a single worldview risks stifling progress by blocking inquiry. The Pragmatic preference for inquiry and results professes that we can continuously invent or develop new ways of seeing the world (ideas) that are better than previous ones.

Ideas are socially constructed for practical purposes. Despite a wide array of ideas included under the umbrella of Pragmatism, there is a common belief in the importance of "know-how, social practices, and human agency" (Bernstein, 2010, kindle location 312). Menand (1997) described Pragmatist beliefs that ideas are not waiting to be discovered "*out there*", but are created by people—they are the tools we use to help us get things done in the world in which we find ourselves.

Regarding what we know and how we justify what we know (epistemology), there are conflicting narratives throughout the Pragmatist community (Bernstein, 2010). One narrative takes an *anti-epistemology* view claiming that the whole notion of epistemology is irrelevant because: (a) there is no clear, universal standard of knowledge (i.e., relativist); (b) all standards of knowledge are historically and socially constructed (i.e., historicist); and (c) one is not committed to a position because it is correct (the truth), but rather because of reasons anchored in cultural, social, and historical contexts (anti-cognitivist). Truth is not the goal of inquiry—the goal is to find results that reduce conflict and promote consensus or collaboration among rivals in a community (Talisse & Aikin, 2008). What is important from a practical humanist perspective need not be deemed objectively true.

There are also a counter-arguments to the anti-epistemological view described above. Namely, that although there are multiple viewpoints of knowledge (relativism), generally, individuals propose that their view is better than others, which contradicts the idea of relativism. From an individual perspective, few individuals subscribe to relativist views of knowledge believing instead that their particular views are best. An counter-argument against historicism stems from the claim that even though individuals in different cultural, social, and historical contexts produce knowledge related to their context, this is not the same as saying that knowledge is inherently socially constructed, and finally challenges to the anti-cognitivist views claim that we can know things and value some ways of knowing over others (Rescher, 2001; Talisse & Aikin, 2008). There are important standards and justifications for what we know, although it is not because of some ultimate or universal Truth, the standards are based more on consensus and coherence within groups of people.

Some commonality appears in a general Pragmatist epistemology that proposes a reconstruction of the theory of knowledge to recognize the interests and limitations of knowers. This epistemology includes three views of knowledge: (a) antifoundationalism—knowledge does not require, nor does it have to have a set of foundational knowledge or principles; (b) fallibilism—all knowledge is open to revision or rejection; and (c) instrumentalism—all knowledge and reasoning depend on one's interests or intentions (Talisse & Aikin, 2008). These views profess that knowledge is conditional and situational. And the value of knowledge depends on its consequences or the actions it invokes. Focusing on action, an interesting set of emerging theoretical perspectives about practice link Pragmatism to the working world and contribute important insights to into the complex nature of practical activity. A general overview of emerging practice theories is described next.

Practice

Emerging Practice theories provide a strong complement to the focus of Pragmatism on the consequences of, or the actions brought about by ideas in the context of everyday life and work. The interest in new perspectives of human activity stems from the ideas that knowledge, human activity, science, language, social institutions, meaning, and human transformation are highly inter-related and mutually constituted within fields of practices (Feldman & Orlikowski, 2011; Nicolini, 2013; Schatzki, 2001). Bundles of interconnected practices define and are defined by the organizations and institutions within which we live and work (Nicolini, 2013). Pragmatism seeks to explain the link between ideas and actions, Practice theories explain how and why actions appear and proceed as they do in the world. As with Pragmatism, pluralism is a defining characteristic of Practice theories.

Three different theoretical views of Practice have evolved recently: (a) Practice as an activity, (b) Practice as multiple activities embedded in systems of values, discourse and power structures, and (c) Practice as the reproduction and innovation of activities and their effects on society (Corradi, Gherardi & Verzelloni, 2010). Among these different views, Practice is studied as either an empirical object or an epistemological process of knowing. As an empirical object, studies focus on the activities, artifacts, and contexts of practice. As an epistemological process, studies focus on the creation and development of knowledge situated in particular collective activities (Corradi et al., 2010). Common characteristics of practice theories are an emphasis on habitualized human activities and purposive human agency entwined in complex and multi-faceted social contexts (Sandberg & Dall'Alba, 2009).

Feldman and Orlikowski (2011) described three principles of Practice theories: (a) a collection of activity that enacts (produces or reproduces) a social order or system, (b) the rejection of dualism in favor of the relations among things, and (c) the mutual constitution of phenomena. Current views of organization and the workplace recognize the complex, dynamic, distributed, novel, unpredictable, social, and emergent nature of human activity—in other words, human activity within complex adaptive systems. The analytical power of Practice theories derives from a non-reductionist or holistic view of the workplace and work—one that is very compatible with a Pragmatist philosophy.

The Practice perspective aims for a deeper understanding of the ways people live and work by taking a process and relational orientation emphasizing the interdependence of activity and performance from the level of the collective or group, which also includes processes of conflict, power, and politics. This interdependence is not only among the individuals in the group, but also includes the important influences and roles of materials, tools, rules, and communities in the work people do (Corradi et al., 2010; Engestrom, 2000; Nicolini, 2013).

Practices formulate and determine social orders by organizing human activities around a set of meanings, identities and behaviors (Schatzki, 2001). Schatzki prefers the term arrangement instead of order and describes arrangements as an organized collection of activities in pursuit of some collective end governed by a set of acceptable rules, beliefs, and hopes.

The interdependencies of people and their material environments vary in different contexts and at different times. Thévenot (2001) articulated different "pragmatic regimes" having different configurations of practices including the relationships between actors and their material environments. The differences essentially characterize practices inherent at micro-, meso- or macro-social levels of analysis. At the micro level (local level) of practice the individual personalizes or customizes activities for personal convenience. This level has minimal social influence except for the historical or path-dependent nature of the practices. At the meso-level of analysis, the activity shifts to the group level with a more conventional view of interaction with the material environment—one that can accommodate more than one individual interacting. An important component of this level is the individuals' use of tools or models to monitor and predict interactions among the actors. The macro-level is the most social level of practice and relies on conditions of legitimacy (e.g., professions) as important influences on practices across larger social groups (Thévenot, 2001).

A major stream of research in Practice theories focuses on activities (Corradi et al., 2010). What people do in organizational settings is the main focus of an activity system (Engestrom, 2000; Foot, 2014). An activity system includes an actor and an object that is the goal or desired result of an activity. In addition, the system includes tools (conceptual and material), rules, a community of relevant actors, and a division of labor (Engestrom, 2000). Thus, any activity (e.g., engineering, design, problem solving, management, production) is a complex system comprised of people, tools, goals, rules, actions, and social structures—along with the inherent conflicts among them. Rather than reducing practice to the actions that people do, a more holistic perspective recognizes the real and powerful effects of the context, artifacts, culture, politics, and institutional logics enfolding a practice.

This brings us to the issue of practicing engineering in organizational settings—specifically industrial and commercial organizations in contrast to academic organizations, although ideally there are many similarities—practically there are fewer similarities. Both types of organizations operate within institutional frameworks that structure their practices (Scott, 2003). And while the logics within these institutional frames differ, the entwinement and mutual constitution of the elements composing their practice fields operate in similar ways.

Implications for Engineering Studies

Looking to Pragmatism, James (1907/1995) noted that in our age of enlightenment the human preference for conceptual, theoretical knowledge marginalizes much of the experiential knowledge gained through our activities. Looking at engineering practice from the perspective of Pragmatism suggests several ideas for framing how engineering works. Pragmatism focuses our attention on the outcomes of the engineering process—not some idealized body of scientific or theoretical knowledge created for engineering in the world. An idea is valuable if it works, not because it is ideal.

The main tenet of Pragmatism is that ideas should yield to the practical. A Pragmatic view of engineering practice perceives it to be embedded within a larger realm of social, cultural, and political systems—the so-called "messy world."

Therefore, the meaning of the work of engineers is described by the consequences of their actions, not some ideals drawn from a traditional natural scientific worldview. Engineering work is necessarily entangled with non-engineering human systems in all of their complexity, subjectivity, and unpredictability.

A reductionist perspective of the world has a strong grasp on engineering—both in the education of engineers and in the practice of engineering (Bucciarelli, 2003). The predominant practices in engineering are anchored in a fundamental hierarchical view of reality with universal laws based on math and science at the top, followed by more localized theories and principles (Bucciarelli, 2003). Near the bottom of the hierarchy is the social world. This hierarchy fits the nature of engineering science that predominates the academy. However, the majority of engineering graduates that go on to practice engineering enter the world of industry. The world of practice in industry is a predominately social world.

The need to recognize and value the social aspects of engineering work is gaining momentum in research and education. It has a longer history in industrial organizations. A good example of the importance of the social systems to engineering work was highlighted in a study of serial innovators (Griffin, Price & Vojak, 2012). In this work, successful innovators described how they bridged the technical and social worlds by considering the social and political systems at work as important variables integral to the creative process. One innovator stated that, "*It is not a project until it is accepted*" (Griffin et al., 2012, kindle location 1696/4194). This emphasis on the consequences of the social process is a core element of Pragmatist and Practice worldviews.

The value of using a practice lens to examine the work of engineering comes from increasing our understanding of what engineers do, how they do it, and why. One of the ongoing criticisms of engineering education is the gap between what students learn and what they need to do in the workplace after graduation. The majority of this work is the practice of engineering—typically in industrial and commercial organizations (Barley, 2005; Heywood, 2005; Trevelyan, 2015). There is a critical difference between the ways engineering is practiced in higher education and the ways it is practiced in the workplace (Heywood, 2005; Korte, Sheppard & Jordan, 2008; Radcliffe, 2006). Obviously, there are strong, systemic differences between the institutions of higher education and industry, although the recognition and appreciation of the consequences of these differences is less acknowledged. Trevelyan (2010, 2014) and Korte et al. (2008) made this point based on their empirical studies of engineering practice that repeatedly showed that practicing engineers do not consider much of their work on the job to be "real engineering." It seems apparent from this work that a particular view of engineering in the academy marginalizes a large part of the actual practices of engineers on the job. For example, a broader view of engineering practice includes important processes of communication, negotiation, coordination, legitimation, conflict, power, politics, management, and organization among others (Korte et al., 2008; Trevelyan, 2010).

Applying Thévenot's (2001) conceptualization of different regimes of practice to the practice of engineering helps to differentiate the various emphases found in practice at different levels of analysis. For example, individual engineers might use and develop idiosyncratic activities of convenience in their specific work tasks. At the next level, work groups of engineers might rely on more conventional practices that help coordinate their work among different individuals in the group and among different groups. This aspect of coordination was an important component of engineering work identified by Trevelyan (2015) in his extensive study of engineers at work. At the macro level of engineering the practices tend to conform to criteria of legitimacy held by the broader communities of applied sciences, business, and society. This categorization scheme provides insights into the sources of friction or conflict that emerge at the interfaces of these levels. Individual practices might more or less fit with group models of practice, which face pressures to conform to accepted or legitimate prescriptions of practice by the profession or community as a whole.

These pressures to adapt were clearly found in a study of the experiences of newly hired engineers learning to practice in the contexts of large organizations. Many of these new engineers began by enacting ways of practicing engineering based on their schooling and consequently they found they needed to adapt to a different set of expectations affecting the practices in their work groups (Korte et al., 2008). Furthermore, they often encountered tensions between their individual practices, the practices of the group, and the legitimate expectations of the organization, the profession, and society as a whole.

The dynamics of the social world are less amenable to the reductionist, objectified, and nomological mindset strongly linked to the natural sciences. Practice theories and supporting Pragmatist philosophies are powerful analytical tools for examining and understanding the dynamics of the practices that make up the organizations in which engineering is a part. Practice theories link the action-oriented and consequential values of Pragmatism to the everyday activities of work and its outcomes. The emphasis is on what people do and what that doing does for society (Corradi et al., 2010). Thus, what engineers do is an important defining principle of engineering practice. And what they do at work largely includes social processes (Bucciarelli, 2003; Korte et al., 2008; Trevelyan, 2015).

The philosophy of Pragmatism and the theories of Practice are relatively new ideas still under development, yet they offer exciting insights for reframing our views of engineering—especially for the profession and the work of engineers. Engineering is a practical endeavor and the principles, beliefs, and values put forth by Pragmatism, along with the analytical power of emerging Practice theories offer a means to work out some of the tensions and shortfalls of more traditional and idealistic views of engineering.

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The Relevance and Significance of Deweyan Pragmatism for Engineering Education

Mani Mina and Iraj Omidvar

Abstract
Focusing on pragmatism of John Dewey, this chapter explores the tectonic theoretical shift that has turned "activity" into the central trope of Western philosophy and has the potential not only to re-locate engineering from the margins of epistemology to its center by reframing the relationship between theory and practice but to permit engineering educators to reconceptualize their work in ways that are dramatically different from how they have traditionally. This chapter will examine these topics by focusing on how American Pragmatism as articulated by John Dewey relates to and informs engineering philosophy. The chapter will also explore some of the implications of his philosophy for engineering education.

Introduction

We are heirs to a long tradition in philosophy going back to Plato and Aristotle that separates and opposes "*theory and practice*" and "*knowing from doing*."(Dewey, 1991) [1].Although the philosophical justifications for the opposition have been comprehensively refuted over the centuries, it continues to shape how we view certain aspects of our disciplines, professions, and political and economic habitats, for example, the gulf between the mind and the body (a gulf whose implications in the U.S. can be seen for example in insurance coverage for ailments that are considered psychological as opposed to physical), the division of universities into humanities fields on the one hand and scientific/technical fields on the other (and the associated pay scales), the division of various fields into pure/theoretical versus practical/experimental, and the gendered division of labor in many scientific and engineering fields versus many fields in the humanities, among many other such divisions within society (Dewy, 1916; Dickstein, 1998; Hickman, 1990, 2001; Hollinger and Depew, 1995).

Modern philosophy of science, as for example formulated by Karl Popper (Dickstein, 1998, p 217) in part emerges from an uncompromising critique of this philosophical tradition we have inherited as well as from a reframing of justifications for reliable, objective knowledge as grounded in how actions are performed and socially critiqued. Thus, modern philosophy of science reflects a major shift that reconnects theorizing with practice (or activity involving problematization, hypothesization, prediction, experimentation, and analysis) and insists on the pivotal role of what Popper calls the "*social institutions*" of science or open/public critique of claims (replication and peer/external review) (Dewey, 1938; Dickstein, 1998)

However, many important implications of this epistemological shift have not been sufficiently appreciated and continue to shape educational policies, practices and beliefs. John Dewey's pragmatism is not only a radical break from that philosophical tradition but offers a comprehensively fleshed-out framework that accounts for many of the implications of the epistemological shift. Although some of the key concepts and arguments of American Pragmatism as a distinct philosophical current were first formulated by Charles Sanders Peirce (1839-1914) and popularized for a general academic audience by William James (1842-1910), it was John Dewey (1859-1952) who developed them extensively in a body of work constituting some 37 volumes [2] written over a span of nearly seven decades. Dewey's version of American Pragmatism – which at different stages during his long career he called "instrumentalism," "*experimentalism*," and in his later works, simply "*technology*" [3]– examines such areas of philosophy as theory of knowledge, metaphysics, ethical and social theory, and aesthetics. A particularly important area of exploration for Dewey was educational philosophy, and he has bequeathed a number of influential works that remain required reading in American colleges of education. In fact, with time the influence of some of his ideas in American education has grown. The Boyer report, for example, references him thus:

"*Undergraduate education in research universities requires renewed emphasis on a point strongly made by John Dewey almost a century ago: learning is based on discovery guided by mentoring rather than on the transmission of information".*[4]

In the following section, we will outline some aspects of his philosophy that relate to engineering education and philosophy of engineering.

***Dewey's Central Concern: "The Formation of Good Ideas* [5]**

The major problem Dewey grappled with at every level of philosophical analysis—whether educational, scientific, aesthetic, political, etc.—is how we can arrive at good ideas (depictions, words, explanations, images, etc.). He wanted to know how in goal-oriented, communal (conjoint or cooperative) activities of humans made possible through communication, we can successfully take the critical step of arriving at good ideas for surmounting difficulties and solving problems.

He believed that not just the happiness and prosperity but the survival of the individual and of society depend on the success of humans in forming good ideas. His philosophy aims at creating conditions that ensure the *continued* possibility of that success. Thus he was after mindsets, mechanisms, and approaches to knowledge communication and creation that are self-correcting, combat intellectual ossification, and resist disciplinary orthodoxies and dogmas. And he sought a society in which the idea and practice of *reform* are deeply incorporated. His epistemological and political models for achieving these goals are scientific and democratic, respectively. Moreover, as will be outlined shortly, his theory of inquiry and philosophy of education have very close affinities with engineering.

For Dewey, what constitutes "good ideas" has to be sought in *activity*, or in his writings on theory of knowledge, *inquiry.* Dewey's philosophy is based on his observations of the living organism. In *Logic: The Theory of Inquiry* (Dewey, 1916), he begins by noting that organisms are already living within an environment. Through their activities, they and their environments change and adjust to each other; thus organisms are in a state of flux and movement. In order for organisms to maintain life they have to seek equilibrium with the environment through activities that change them and the environment. They come out of balance with their environment (they become hungry, are threatened or hurt, etc.), and they seek to restore the balance. This *seeking* to restore balance foreshadows his theory of inquiry. For example, when an animal is hungry, it will look around and search for food. Through experience of finding food, it forms a store of knowledge, in some animals in the form of useful habits and in higher-order animals and specially humans in the form of both useful habits but also a store of memories (Dewey, 1916).

Organisms through their movement to and from disequilibrium and equilibrium refine and improve their methods. He refers to this continual refinement and improvement as "*growth*." Thus, in *Democracy and Education*, Dewey writes that the aim of life is growth, which he defines as "a self-renewing process through action upon the environment" (Dewey, 1962). In *Reconstruction in Philosophy*, he writes that: "*The process of growth, of improvement and progress, rather than the static outcome and result, becomes the significant thing. . . . Not perfection as a final goal, but the ever-enduring process of perfecting, maturing, refining is the aim in living. Honesty, industry, temperance, justice, like health, wealth and learning, are not goods to be possessed as they would be if they expressed fixed ends to be attained. They are directions of change in the quality of experience"(Dewey, 1936).*

Of particular relevance to philosophy of engineering is that Dewey sees this growth as being mediated, that is, being achieved through means, methods, and ways. Dewey's preferred word for describing the character of this mediation is "*tool*." Organisms "*use*" these means or tools to effect change. Thus, in pragmatic theory of knowledge, technology – its use and production – is closely associated with activity and is central to the theory.

According to Dewey, one key tool humans have created in the communal activities involved in the pursuit of equilibrium is communication through language. Several important features of Dewey's philosophy find expression in the previous sentence. First, language, according to Dewey, is a technology bound up with (or subsumed under) activity. Second, activities aimed at solving problems are chiefly social or communal. He defines language broadly to include "*all means of communication such as, for example, monuments, rituals, and formalized arts. Language is the record that perpetuates occurrences and renders them amenable to public consideration*" (Dewey, 1991). He writes that the meaning communicated through language "*is established by agreements of different persons in existential activities having reference to existential consequences*" (Dewey, 1991). Through language, we evoke "*different activities performed by different persons so as to produce consequences that are shared by all the* *participants in the conjoint undertaking*" (Dewey, 1991).

By emphasizing the *commun-* in communication and the development of language, Dewey underscores the intimate connection among community, language, and *thinking*. According to Dewey, the human ability to think is "*a product of the fact that individuals live in a cultural environment. Such living compels them to assume in their behavior the standpoint of customs, beliefs, institutions, meanings and projects which are at least relatively general and objective*" (Dewey, 1991). In short, thoughts, theories, and concepts are also tools. Dewey considers language the "*tool of tools*" [2] and thinking, a particular form of technology use.

In this model, the formation of ideas – theorizing – is the pivotal stage for humans in completing the communal activity. Stripped of his broader philosophical outlook, this pivotal stage (or Dewey's theory of inquiry) is the familiar scientific method, which he variously calls the process of inquiry, critical or reflective thinking, or a "*complete act of thought*" (How We Think) (Fishman and McCarthy, 1998), which he divides into five steps, which are very similar to those involved in problem solving that engineering programs teach students and can serve as a good point of departure for understanding how these steps are used in his philosophy. Dewey's five steps to thinking are *"(i) a felt difficulty; (ii) its location and definition; (iii) suggestion of possible solutions; (iv) development by reasoning of the bearings of the suggestion; (v) further observation and experiment leading to its acceptance or rejection; that is, the conclusion of belief or disbelief*" (Fishman and McCarthy, 1998).

A complete act of thought begins with a problem, a term he uses in a very broad sense to cover a wide range of phenomena: a felt difficulty, puzzlement, a major obstacle, an opposing force or conflict, a break in expectations, an anomaly, etc. The problem itself arises from already on-going activities of the inquirer. Dewey considers step (iii), suggestion, "*the very heart of inference; it involves going from what is present to something absent. Hence, it is more or less speculative, adventurous. . . . .The Suggested conclusion so far as it is not accepted but only tentatively entertained constitutes an idea. Synonyms for this are supposition, conjecture, guess, hypothesis, and (in elaborate cases) theory"* (Fishman and McCarthy, 1998). On step (iv), reasoning, he writes, "*The process of developing the bearings--or, as they are more technically termed, the implications--of any idea with respect to any problem, is termed reasoning. As an idea is inferred from given facts, so reasoning sets out from an idea*" (Dewey, 1991). Dewey finds "*theory*" in steps (iii) and (iv), that is, as stages in inquiry. He does not contrast "*theory*" with activity or practice as does the philosophical tradition we have inherited from the Greeks, but he sees theory as part of practice or framed by it within the inquiring activities of agents.

For Dewey, steps (ii) and (v) identify the key stages of the interaction between the organism and the environment. Of importance to the philosophy of engineering are Dewey's explanations of those steps. He writes (*Logic*) that in "*the more complex organisms, the activity of search [ii and v] involves modifications of the old environment [the environment in which the problem has been encountered], if only by a change in the connection of the organism with it*" (Fishman and McCarthy, 1998). In other words, steps (ii) and (v) require "*the transformation of the situation . . . . [which] is existential and hence temporal.*" In the search, the inquirer goes to and, in the process, interacts with and changes the environment. Thus, in Dewey's pragmatic model of knowing, activity and practice are the broad framework for what it takes to know, which is a stage in the "*modification of the old environment" and "transformation of the situation*" through the use of conceptual and other tools. The modification and transformation are not what, say, a special field of knowledge such as engineering does; rather they represent what any community that is trying to know something must do.

Education and Reform in Dewey

Dewey is, first and foremost, a reformer. In *Experience and Education* (Dewey, 1936)Dewey argues that in a sense, a good education aims to free students of their impulses (see the next subsection for his ideas on growth). He considers real freedom to be "*power to frame purposes, to judge wisely, to evaluate desires by the consequences which will result from acting upon them; power to select and order means to carry chosen ends into operation*" (Dewey, 1936). For Dewey, the starting point of all knowledge is the lived experience of the individual in the world of the common sense. For individuals, knowledge begins from what they value and already understand of their lives. He writes, "*Natural impulses and desires constitute in any case the starting point. But there is no intellectual growth without some reconstruction, some remaking, of impulses and desires*" (Dewey, 1936). Dewey is concerned that individuals in society and in school often do things either impulsively or by force of authority. The external constraint imposed by society is useful in that it moderates and controls impulses. But he believes the better source of constraint or "*inhibition*" is through one's own reflective or critical thinking (Dewey, 1936). In a memorable passage, Dewey writes "*thinking is stoppage of the immediate manifestation of impulse until that impulse has been brought into connection with other possible tendencies to action so that a more comprehensive and coherent plan of activity is formed. Some of the other tendencies to action lead to use of eye, ear, and hand to observe objective conditions; others result in recall of what has happened in the past. Thinking is thus a postponement of immediate action, while it effects internal control of impulse through a union of observation and memory, this union being the heart of reflection. What has been said explains the meaning of the well-worn phrase* "*self-control*." The ideal aim of education is creation of power of self-control (Dewey, 1936).

Goal of Education for Society: Creating Conditions of Continued Growth

Dewey believed that through the exercise of intelligent freedom or "self-control," students may be in the best position to ensure continued conditions of growth. Dewey's educational goal is all around growth, not only for students but also for society (*Democracy and Education*) (Dewey, 1916). And again by growth he means a type of interaction with the environment through which both the organism and the environment mutually adapt to and shape each other. He wants to provide society with what it needs to perpetuate itself, to create conditions of growth that are most conducive to further growth. This suggests the value of students' autonomy and their ability to shape the educational experience.

DEWEYAN EDUCATIONAL PHILOSOPHY AND SOME IMPLICATIONS FOR ENGINEERING EDUCATION

As mentioned, for Dewey, the goal of education is freedom, "*power to frame purposes*," to judge wisely, to evaluate desires by the consequences which will result from acting upon them; power to select and order means to carry ends (purposes) chosen by the student into operation. The final goal is creating conditions of growth through democratic social and institutional arrangements, with ever greater intelligent participation of members.

Through open channels of communication and commitment to dialogue and criticism, Dewey hoped that both society and the individual could create conditions conducive to forming good ideas. These good ideas will lead to better decisions that result in greater flourishing and development of the individual. Through the process of open communication (as part of society's general projects of inquiry), both the individual and society will be transformed for the better.

These ideas are in broad agreement with contemporary philosophy of science. As Karl Popper writes, "*objectivity is closely bound up with the social aspect of scientific method," which results "from the friendly-hostile co-operation of many scientists*" (Dickstein, 1998). Of crucial importance is "*free criticism*," (Dewey, 1938) which takes place in "*the various social institutions" (emphasis his) such as "laboratories, the scientific periodicals, and congresses*."

There are at least four key aspects of Dewey's theory that have important uses and implications for the philosophy of engineering education. These involve the development of an attitude of skepticism, valuing change individually and organizationally, emphasizing the centrality of context, and the importance of teaching the function of theory in the process of inquiry.

First, Dewey argues that knowledge never leaves the realm of theory and remains forever subject to change, and inquirers should leave open the possibility that their firmest ideas and most cherished solutions may need to be modified or scrapped. The effectiveness of science and engineering emanates exactly from this characteristic. And engineers and scientists would do well to pass on this mindset to their students by creating an environment that genuinely encourages this skeptical attitude, which can be adopted primarily in *practice*, during the activities involved in inquiry Students need a safe environment and enough time and resources to question and reject received explanations and to attempt to find better ones.

Second, Dewey argues that all inquiry involves transforming the environment. Knowledge making is by definition transformative. The type and extent of transformation, of course, has to do with the goals of inquiry. For Dewey, an inquiring mind is going to change the environment in some way, disrupt the old ways of doing things. It will be respectful of past ways of doing things but will not revere those ways so much so as not to try new ways. Thus, the educational environment should anticipate, encourage, and adapt to such changes. As lines of inquiry in pursuit of meaningful answers to problems that genuinely matter to students are pursued, instructors should be open to changing their syllabi, their projects, their teaching strategies, etc. And they should gear their instructions to specific needs of students. Departments need to understand this necessary step in inquiry and accommodate instructors. Such changes cost money and resources, but if the goal is the teaching of *thinking*, then Dewey at least would argue that the cost is well spent, since the alternative is directly inimical to thinking.

Third, Dewey argues that facts are facts in the context of inquiry. They are "*operational . . . . [and] not self-sufficient and complete in themselves. They are selected and described . . . for a purpose, namely statement of the problem involved in such a way that its material both indicates a meaning relevant to resolution of the difficulty and serves to test its worth*" (Dewey, 1916). One implication of this position is that the teaching of facts outside the context of inquiry is counterproductive. Schools spend a great deal of time teaching facts outside the context of inquiry. And students spend much of their time memorizing such facts, which they promptly forget after tests. If the inquiry genuinely matters to students, they will seek out the facts and remember them long after the problem has been solved. By not requiring students to memorize large quantities of decontextualized facts, time is freed for inquiry, including the pursuit of facts that are relevant to the inquiry.

Fourth, Dewey argues, "*science takes its departure from commonsense*," *which consists of "beliefs, conceptions, customs and institutions*". Dewey emphatically argues against teaching to students the findings of science as ready-made ideas to believe in. This is an issue of belief. It is not enough merely to repeat that all findings of science are hypothetical or theoretical. Rather, students should come to see the theory in the context of a meaningful inquiry, which advances their vision and capability, and helps them grow. Only while the theory plays its function in the process of inquiry can it be understood as did the scientists who came up with the theory and examined it in the first place.

But there is a much deeper issue implied in the observation that the starting point of science is the world of commonsense. For the student – that is, from within the student's schema of knowledge – a theory taught outside the context of inquiry remains a dogma, and a student who believes in it has practiced exactly what science is designed to circumvent: accepting claims on mere authority, that is, accepting claims without examining the reasons and evidence. Here Dewey makes an important observation. He argues that students accept such dogmas because of factors that are external to the subject matter of inquiry: Gaining approval and avoiding sanction, promise of later understanding, etc. To say that an educator should create conditions in which the inquiring minds of students are engaged requires that problems be relevant and of importance to students; the problems should matter to students' lives; they should, one way or another, fit in with the broader constellation of concerns of students' needs, aims, and values.

For example, for Dewey, expecting students to register in classes for no other reason than four years in the future they will be able to get a good job is tantamount to expecting students to engage in a set of activities that, in terms of the subject-matter, is not only *irrational* but detrimental to their intellectual development. To use Dewey's framework, students who engage in activities (processes of inquiry) whose purposes they do not understand are acting by means of external constraints. Students who do not understand and care for the problem cannot meaningfully search for possible solutions, formulate questions, and test their guesses. Consequently, their activities will be directed not because of the intelligent operations of their thoughts in an environment geared towards learning something about the subject-matter, but because they want to receive a certain grade, or to graduate and earn a certain salary, etc. In such a context, students are learning something, but what they are learning is that the subject matter is irrelevant to their lives and that if they wish to surmount a problem that does genuinely matter to them (receiving a good grade, a good job down the road, etc.), they have to engage in a set of irrational and arbitrary activities that they do not care about.

These considerations led Dewey to grapple with a critical educational problem: the connection between student interest and curriculum. When students enter a disciplinary discourse community such as electrical engineering, they are confronted with a set of disciplinary problems. If the problems the discipline is facing or has faced and solved are also not problems for students, they will not enter the process of inquiry. According to Dewey, an educational arrangement in which students do not find the subject-matter of study inherently interesting has failed on several levels, perhaps the most obvious being, the failure of the educational program to offer students an opening for thinking.

But Dewey considers the harm done to the discipline and society equally disconcerting. Given his belief in the urgent necessity of the possibility of continued reform (growth) both in science and in society, Dewey has a special esteem for schools, which he considers to be social spaces in which ideas about change in science and society can be formed and tested. As Fishman and McCarthy write, "*Dewey wants to develop an experimental spirit . . . in pupils. For . . . although Dewey cares a great deal about student mastery of subject matter--insisting that to be part of a community is to share common language, values, and practices--he is equally concerned that students develop critical methods or habits of thought so that communal traditions can be tested and revitalized.*" (Petroski, 2010).

For Dewey, a genuine learning environment (a disciplinary discourse community) not only permits but also encourages and expects challenges to its established views and assumptions and patterns of professional and administrative behavior.

Concluding Remarks

As Gravander (2014) points out, "*In contrast to the philosophy of science's relatively long history as a field of inquiry, the philosophy of engineering has only recently begun to emerge*" (see also Grimson, 2014). This delayed emergence is itself a consequence of the continued presence and persistence of the traditional epistemological framework that modern philosophy of science replaced. As Larry Hickman points out, the tradition in philosophy we have inherited from the Greeks makes a distinction between theory and practice and sets theory above practice and in fact makes a further distinction between practice and production and sets practice above production (Hickman, 2001). In this scheme, theory, the highest knowledge is the contemplation of permanent forms, the true reality behind the multiplicities of the perceived world. Participation in the activities of moral and political life of society are also valued if they are informed by the insights of theory; least valuable is the work of the producers, artisans, that is, blacksmiths, carpenters, and other proto-engineers and makers of things.

Although in all major currents of contemporary philosophy, "*practice*" has become the central epistemological trope, many disciplines, including engineering and engineering education, justify their curricular choices and pedagogic practices in terms that make a sharp distinction between thinking and doing, between thought and action, between theory and practice.

Deweyan pragmatism offers one of the most fully developed responses to the philosophical tradition that separates theory and practice and proposes an alternative theory of knowledge based on the idea of inquiry that repositions engineering as a paradigmatic discipline within the constellation of academic disciplines. In pragmatism, thoughts and theories are conceptual *tools* used within some stages in inquiring *activities*, which always require some form of *modification* or transformation of the existing situation and environment. Thus, pivotal concepts of pragmatic theory of knowledge are activity (practice, action, doing, etc.), tool (technology), and change in environment (experimentation) aimed at overcoming obstacles (problem solving) encountered by the community. Together, these concepts provide a framework that is easily recognized by practicing engineers[2: 7].

Deweyan pragmatism also offers a powerful framework for engineering education. By not adopting the theory-application dichotomy, and by instead offering a model of inquiry that carefully defines activity and frames thinking and theorizing as a step in activity, pragmatism allows engineering educators to think productively about the connections among the student, the discipline, and larger society and about the role of purpose and value in engineering education. The framework allows engineering educators to incorporate concepts that are often seen to belong outside the domain of a "*practical*" field. In Deweyan educational philosophy, the goal of education is freedom, that is, the student's ability to formulate intelligent purposes. And a Deweyan philosophy of engineering education would insist that students cannot be presented with unchanging goals of their education, unchanging results of other people's inquiries as "*knowledge*," and unchanging paths to achieving those results as "*method*," and then expected to become inquirers.

An educational program along Dewey's pragmatic lines would insist that engineering students participate in formulating the ends and means of their activities, that is, engage in rational assessment of values, whether accepted values (standards) or pursued values (goals), at every stage of their education. Such an educational program would encourage students to formulate their goals and interests, critique them from multiple angles, settle on some goals, actively think about and research the routes to achieving those goals, while remaining open -- given the resources available -- to revising both the paths and the goals.

Notes

[1] Dewey, John. *Democracy and Education*. P. 265. 1916. The Free Press, NY.

[2]The 37-volume collection, edited by JoAnn Boydston, is grouped as *The Early Works, 1882-1898*, *The Middle Works, 1899-1924*, and *The Later Works*, published by Southern Illinois UP, Carbondale, IL.

[3] Hickman, John Dewey's Pragmatic Technology. Page 3.

[4] Page 15. The Boyer Commission on Educating Undergraduates in the Research University. *Reinventing Undergraduate Education: A Blueprint for America's Research Universities*. State University of New York—Stony Brook, 1998.

[5] An earlier draft of this section appeared in Mani Mina, Iraj Omidvar, and Kathleen Knots, "Learning to think critically to solve engineering problems: Revisiting John Dewey's ideas for evaluating engineering education," presented at the 2003 ASEE Annual Conference, Nashville, TN, June 2003.

[6] Hickman, 44, also 58. John Dewey's Pragmatic Technology.

[7] Consequently, in the Deweyan pragmatic approach one can argue engineering whose aim is to explore, modify, invent, maintain, and change things is at the center. Therefore, the engineers are the agents that would bring actions to go from "Thoughts to Things." They are problem solver and problem definers and at times problem creators. They are the modern artisans who change our lives with technology as their main weapon of expression.

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Engineering Insight. The Philosophy of Bernard Lonergan Applied to Engineering

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Abstract—This paper presents the application of Bernard Lonergan's seminal work, *Insight* to the Philosophy of Engineering. Using a pragmatic theory of knowledge as a lens for examining the nature of engineering design as activities of knowing and willing, Lonergan's approach offers a knowing-based approach with the flexibility needed for an epistemology of the many-sided activity of engineering. With his account of the basic method of the human mind underlying specialized methods, he also offers a basis for unifying the theory and pedagogy of engineering. Moreover, in carefully relating knowing to willing, Lonergan's work provides a basis for a conception of engineering that gives due recognition to its ethical character and to the need for engineering virtues. This knowing-based view of engineering, focused on 'engineering insight,' provides the basis for a core, discipline-neutral approach to engineering. It proposes an engineering education centered on norms inherent to the knowing process, specifically attentiveness and intentionality. These norms in turn provide a source for defining and developing engineering virtues and character.

INTRODUCTION

The philosophy of engineering is a developing field, and constitutes a difficult challenge.(Goldman, 2004). At its heart, the polyparadigmatic and hybrid nature of engineering poses a challenge to understanding of engineering. An engineer often uses the knowledge and techniques of any number of arts and disciplines in solving engineering problems and requires creativity to give existence to that which has '*never been*.' As such, engineering is a discipline that is searching for an identity, an identity to help address the breadth and depth of the educational experience needed to reach what is required at a bachelor or master's level. (Grimson, 2014) Hence, explorations into the philosophy of engineering can be of significant value to the engineer, to the engineering educator and to the philosopher interested in the question of "*What is engineering*?" Philosophy as a whole, and epistemology in particular is about asking fundamental questions (Schmidt, 2013), including questions about engineering in which we are looking for a unity behind the diversity presented to us by contemporary culture. Many valuable treatments of engineering philosophy specifically aim to distinguish engineering from science. (Floorman, 1987; Vincente, 1990; Bassett, 2014), or from art (Bucciarelli, 2003; Cross, 2007).

One of the key challenges to Philosophy in the Post-Modern era is the challenge of addressing the overall problems of truth and value in the face of relativism; the challenge is to look for the universal, if indeed it exists: are there exigent patterns for correct knowing in the face of subjectivity? The present work leans on particular developments in epistemology applied to the philosophy of engineering. In particular is the seminal work of Bernard Lonergan, *Insight* first published in 1957. (Lonergan B. , 1992) For Lonergan and philosophers following his lead, the assertion is that in fact we can discover the possibility and limits of human knowing, that in knowing we discover the criteria for correct knowing. (Cronin, 2010) This challenge is addressed not by epistemological theories, but rather by exploring the data, the experience of human knowing; knowing in the context of subjectivity, with reasonable probability, ways that provide an integrating framework that is transcultural and applicable beyond the pluralism of cultures. The core of this work centers on the concept of *insight*, and the foundational text of that same name (Lonergan B. , 1992) holds that "we come to know about the activity of understanding by adverting to what we do when we understand something correctly." (Cronin, 2010)

> *"By insight, then, is meant not any act of attention or advertence or memory, but the supervening act of understanding… its function in cognitional activity is so central that to grasp it in its conditions, its working, and its results is to confer a basic yet startling unity on the whole field of human inquiry and human opinion."* (Lonergan B. , 1992, p. ix)

This unity in the field of inquiry, indeed in the field of epistemology as a whole, is one of the central achievements offered by Lonergan. The point of his *Insight* is to discover the possibility and limits of human knowing from within the process. (Cronin, 2010) This work proposes the philosophy of consciousness method developed in *Insight* as a means for distinguishing Engineering from the polyparadigmatic arts and sciences often used in engineering.

INSIGHT AND THE METHOD OF THE HUMAN MIND

Lonergan's work provides a solid foundation for investigating the various methods of knowing used in engineering. It does so by tracing all forms of knowing -- from everyday common-sense to the most specialized pure science -- back to a common underlying method which he calls the "*procedures of the human mind"*(Lonergan, 1992, p 4.) This procedure or method is discoverable by "*interiority analysis*," by a concrete investigation of the operations of knowing and the relationships among these operations. This investigation is made possible by a dual presence in knowing – of things to ourselves and of ourselves to ourselves. Because each of us is a knower and because each of us is at least tacitly aware of our operations of knowing, we can test Lonergan's account against our own knowing to see if it is consistent. What he challenges us to is a personal and collective investigation into the operations of our own knowing, with an end being the self-appropriation of our knowing (Lonergan, 1992, pp 14 – 17). The result is a consistent, general template for all knowing, and in his observation, one that is tailored differently for specialized forms of knowing.

Beginning with the concept of insight, Lonergan focuses much of his work on the question, "*what do I myself do when I come to know?*" In his answer, Lonergan develops the method of the human mind, around three central operations: *experiencing, understanding*, and *judging*. He argues that this method underlies all specialized forms of knowing. This basic heuristic method is tailored in various ways to meet the particular requirements of everyday life, as well as the specialized contexts of mathematical and empirical science. (Lonergan, 1992). In the *method of the human mind*, the emphasis is on the individual thinking – the data of the exploration is within the subject doing the thinking. Thus the individual, in their subjective context, the one experiencing provides us with the data for the inquiry. (Cronin, 2010) Consequently, this is a theory of cognition centered in an exploration into the conditions for insight that relies upon adherence to a norm of attentiveness, to our striving to make sense of the data. Questions about our thinking about an experience of some object (*e.g.,* "*What is it?*), promotes us from experiencing to attempts to understand; Experiencing and understanding are two distinct activities. Understanding, then, is to find the form, pattern, meaning, or significance of what we have experienced or observed. These intelligible forms are the fruit of successful inquiry, where inquiry (questioning) and imagination yield insights, which are then expressed in concepts and definitions to provide a formulation of the understanding attained.

Lonergan begins his inquiry with the question "*what am I doing when I am knowing*?" His answer is that the knower is doing several things – experiencing, understanding and judging. To know requires each of these operations and in the proper relation. Experiencing provides the data, in which understanding discovers an intelligibility or form. The intelligibility or form discovered then needs to be judged in the light of the data before it can be affirmed or denied as really so, as warranted by sufficient evidence. Without an understanding there would be nothing to judge and, without experiencing, nothing to understand. Without understanding, experiencing lacks intelligibility and, without judging, understanding is not yet distinguished from misunderstanding. The operations are functionally complementary: they complete and perfect each other. Each is characterized by intentionality, by being directed toward being and truth. The impetus they give us toward reality may be thematized in two questions – in the query "*what is it?*" explicitly or tacitly raised about the data of experience and so leading toward understanding, and in the query "*is it really so?*" raised about our understanding and so leading us on to judgment. Only when both of these questions have been properly answered have we acquired knowledge.

In reflecting on these operations, Lonergan's position is that we find norms built into them that set standards for successful knowing. Others have termed Lonergan's formulation of these norms his "*be-attitudes*": "*be attentive, be intelligent, be reasonable, be responsible*." (Dunne, 1995, p. 6) To notice or experience what is going on, we must pay attention. Disconnecting monitoring equipment or avoiding inspections, yields a lack of data that might reveal pending malfunctions. Understanding the data, requires exercise of our intelligence by searching for patterns. Collecting data without analyzing it will never yield understanding. Similarly, if we are not reasonable in judging some understanding in the light of the evidence, we will not be able to distinguish understandings from misunderstandings or fact from fantasy. That is why in court trials we insist on proof "*beyond a reasonable doubt*," on judgments warranted by the evidence to such an extent that there is no other reasonable conclusion. At the ethical level of knowing, which will be considered below, we must "be responsible" by willing consistently with our knowing.

A Objective Knowing

As a theory of cognition rooted in self-appropriation, the question remains as to how these operations of the mind can yield objective knowledge of reality. This opens the question of objectivity, and how the operations of knowing relate to objectivity. Lonergan argues that these operations of experiencing, understanding and judgment can do this, in part, because of the intentionality of the subject, and a resulting relation and engagement of the knower with the known. This engagement varies from experiencing to understanding to judging and, as a result, Lonergan contends that objectivity has three interdependent aspects: *Experiential*, referring to the objectivity of givenness, *Normative*, referring to understanding beyond the subjectivity of our feelings and fears and *Absolute*, referring to the judgment of something being so, and (Lonergan, 1992, pp 402 – 407).

Grasping the objectivity of givenness is part of our knowing from our experience. What is present to us in experience, when one is attentive to the data, is the realization that the data in front of us sets objective limits to possible understandings and judgments. Recognizing that limitation is the first step toward objectivity. Conversely, if the would-be knower is inattentive, the data set will be insufficient for understanding the relevant reality. Data by itself is not reality because, as data, it is still lacking the form or pattern (or order) that is part of the reality of the object. Our intelligence is needed to discover form and the crucial moment in the discovery of this form is an instant of insight. With insight, we discover the possible source of an oscillation, the possible fit of a curve, the possible relationship to a part of a problem or potential solution. Unfortunately, as Lonergan says, insights are "*a dime a dozen*" and are often mistaken. Forms may be partly imagined as when we too hastily recognize a familiar pattern that is not quite present. However, because insights uncover the possible order in reality, they are essential to the development of objective knowledge. Their objectivity depends on giving intelligence free rein by a thorough and penetrating search for patterns.

However, to distinguish understandings from misunderstandings, another aspect of objectivity is required, what Lonergan terms its "*absolute*" aspect. In this aspect, we determine the conditions necessary for something to be so, *e.g.* for an accused person to be guilty "*beyond a reasonable doubt*." By examining our understanding, our hypothesis, in the light of the data, we can then conclude whether the necessary conditions for that conditioned judgment really being so have in fact been met. Lonergan calls this absolute aspect of objectivity reaching the "*virtually unconditioned*." He uses that term to indicate that we have reached a condition where all of the subjectivity removed, a judgments whose conditions have been fulfilled. This gives us the "*absolute*" aspect of objectivity because, with all conditions met, the conditioned has to be so. It is not a matter of what we wish or favor, but a matter of the relation of a conditioned to its condition(s). To the extent that we confine our judgments to this relation, they can be objective.

Intertwined with the absolute and experiential aspects of objectivity is what Lonergan terms *Normative Objectivity*. This is the aspect of objectivity that steps beyond the subject, the aspect of objectivity that opposes the rash judgment, the wishful thinking – the rationality amidst irrational thoughts applied to understanding something. It centers on the desire to understand, especially the desire to understand unconditionally exclusive of feelings and whims, to sort out the relationships and interconnectedness among possibilities. This normative objectivity is an aspect of our process of understanding that distinguishes among sound/meaningful and unsound/meaningless questions. At its best, normative objectivity strives to be rational in the formulation of understanding – not to be driven by belief or propaganda, or one's insecure resentments or even the trends of what passes for acceptable in one's culture. Rather, normative objectivity seeks that which is normative – the desire to know, the desire to base one's understanding of an object by means normalized against the whims of the subject seeking understanding. These aspects of objectivity: absolute, normative, and experiential all support our processing of insights into things that are known.

B Patterns of Knowing

Lonergan's theory of cognition centers around experiencing, understanding and judging, recognizing the roles of absolute, normative and experiential aspects of objectivity. The questions remain about just how we, as we try to self-appropriate how we know, are supposed to reach objective knowledge or what, in general epistemological terms, is referred to as justified true belief. Self-appropriation asks that we examine questions central to the process of knowing such as: "*Where do the conditions that have to be met to reach the virtually unconditioned come from?*" "Who decides what they are and when they are met, and how do they decide?" When we achieve an insight into some data, we discover a pattern and we arrive at an understanding. That discovery can be facilitated by good imagery, by careful observation and analysis, by having in mind a variety of patterns characteristic in such situations. In the end, though, insights require a creative synthesis of elements of the data, in particular if we are attentive to the various aspects of objectivity. Is that understanding correct? It will be if all the conditions required for it to be so are met. But how are those conditions to be discovered? Here, again, we need experiencing, understanding, and judging. This pattern of knowing is not circular but rather is cumulative.

An example of this pattern (Fitzpatrick, 2011) can illustrate how we can self-appropriate our knowing. Assume you go into a room in the upper story of your house. Your eye sweeps over a dark patch on the carpet, one that was not there before – an experience that provides data. Seeking understanding, you wonder what it is and why it is there. You put a finger on it, examine a drop, notice its silvery texture, and conclude it is water, but water from where? More data gleaned from experience enhances the experiential aspects of your understanding. You begin thinking of possible causes that could explain the presence of the water. Were the wash basin along the wall to have over-flowed, water might have run over and caused the spot. Similarly, a radiator leak could be responsible, or possibly a leak from the pipe under the floor. Each of these possible explanations of the data represents an insight and an understanding. Which is correct? Recognizing and stepping beyond my annoyance of the last radiator leak allows me to normalize my exploration.

In seeking objectivity, your mind considers the conditions that would have to be met for each to be true and is able to discount each. The tap in the wash basin is turned off and the sink appears dry and has not been used for a long time. The side of the radiator is dry. The pipe under the floor would more likely leak down. At this point, something strikes you on the head and you feel it with your finger and look up. It is water, there is a spot on the ceiling, and rain can be heard on the flat roof. There is sufficient evidence for a highly probable judgment that the roof is leaking. You were able to establish the conditions that would have to be met for explanations of the spot to be true. You do this by applying what you know about the properties of water, about usage of the basin, about the sound of rain on the roof, etc.

Here we see the importance of what Lonergan calls the scissors-action in knowing. We move up from the data and down from general patterns learned through education and work in the area. These actions work through applying different absolute, normative and experiential aspects of translating the subjective experiences into objective knowledge. This implies, and Lonergan suggests, that there are in fact significant patterns to how people pattern knowing. The scientist may, for example, have a familiar set of differential equations in mind ready to be applied to reveal patterns in the data. Similarly, an engineer's education and practical experience will make him or her familiar with an abundance of patterns of data and of relations of causality and dependence – and these patterns can be brought to bear both in achieving insights and in establishing the conditions that must be met for something really to be so.

Each of these particular patterns of investigation set up types of knowing, such as classical, scientific, or statistical knowing, which are specializations of the general method of the human mind. These specific heuristic methods to support knowing are reasonable and proper to each discipline. (Cronin, 2010) A particularly interesting expression of these heuristics is the empirical methods proper to the modern understanding of natural science. These include the application of classical and statistical laws as they are understood by the individual, developed into theory, and adopted by the community. The key point here is that the various forms of scientific knowing are demonstrated to be examples of the same underlying method of the mind as common sense knowing. However, the tailoring of methods to the objects under study sets up the expectations for different patterns of knowing, that serve different purposes in human society, and the expectation that such patterns, or meta-patterns of knowing have developed, and will continue to develop. Lonergan documents sets of these meta-patterns of knowing for the empirical sciences, and comments on their limits: "*Pure science aims immediately at reaching the immanent intelligibility of data and leaves to applied science the categories of final, material, instrumental, and efficient causality*." A fascinating characteristic of engineering is its practical and instrumental nature, which gives it an intermediate position between the empirical sciences and common sense: As a discipline, and a way of approaching developing artifacts of value it necessarily draws on both forms of knowing. However, in showing how both scientific and common sense knowing are specialized forms of the underlying method of the mind, Lonergan provides a basis for a unified view of these disciplines, with their varied procedures (Lonergan, 1992, pp 244- 253).

This general method of the human mind is the most important heuristic (Greek *heurisko,* to find or discover) method. In applying it in different contexts, in everyday life, in physics, in engineering, we tailor it to the needs of the field. Because of the complexity of engineering, a variety of tailored versions are utilized. Sometimes engineering needs scientific precision, sometimes something close to the "*good enough*" standard of common sense will do. In determining the flight path for a planetary exploration vehicle, great precision is required. The mission will be expensive, not easily repeated, and with little margin for error. The experiencing in the process of experiencing, understanding, and judging will need to be carefully controlled to avoid distorting factors and noise. Our understanding will need to be comprehensive and precise and will need to view things in relation to each other rather than simply to ourselves. Judgment will require a very high degree of certainty, based on precise and exhaustive data, to ensure all conditions for a particular trajectory are met.

In everyday common-sense knowing, our requirements are far different. Because common sense knowledge is for living and because we live in the here and now, common sense does not seek universal truths. Its practical purpose requires prompt action, meaning any precision beyond what is "*good enough*" is a waste of precious time. Similarly, common sense has no time for defining its terms or for developing a technical vocabulary, if everyday speech is workable. It prefers descriptive to explanatory definitions, terms based on how things appear rather than terms indicating the relation of things to other things in some order or scheme. Thus, "*dutchman's breech's*" is what common sense would call the plant *dicentra cucullaria*. These terms carry with them the weight of social construction and agreement, but also of what has become 'known' by the community, and when used correctly, the individual.

We often need to act quickly, in a simple context, where actions taken according to well-known rules of thumb may be enough. At such times, our experiencing need not be confined to controlled experiments. A general view of the situation may be sufficient. Our understanding may need only to discover which rule of thumb seems to fit the data best. Our judgments may require not near certainty, but only moderate probability. These are some of the ways in which experiencing, understanding, and judging may be tailored. There are countless others. For example, various fields of engineering will have widely differing methods of data-collection. Each serves a tailored version of experiencing, understanding and judging.

C Insight

This theory of cognition presented in *Insight* posits that we can generate ideas out of the images derived from our senses, and those of our imagination. This implies a structure in the mind that enables one to move from images, from the sensible to the intelligible, from the unknown to the known, giving direction to our searching. This is not a random insight, but rather guided by the activities of experiencing, inquiry and understanding. But these are purposeful activities: the aim of the questions, of the inquiry is the understanding reached from the achievement of insight. (Cronin, 2010)

In Lonergan's terms, inquiry, insight and formulation embody a norm of intelligence, a general and generalizable set of guidelines that orient our search for understandings. Because understandings may be misunderstandings, we cannot stop with inquiry, insight or initial formulations, but must go on to ask the critical question, "*is it really so*?" which is particularly important in the context of conflicting data. The process of answering this question thematizes our desire to move through critical reflection to judgment. Judging marshals and weighs the evidence to assess the adequacy of our understanding. The evidence is adequate if it shows that the conditions necessary for something's being so are all met. If they are met, within the context our knowing reaches a "*virtually unconditioned*" state, whose conditions for justified belief are fulfilled. It is no longer is conditional and, until proven otherwise, must be true.

The norm embodied in these operations of judging is that of reasonableness. The overall method is adjusted based on the perceived need for timeliness, precision, comprehensiveness, universality, and/or completeness. (Lonergan B. , 1992). This is where the viewpoint of knowledge is critical, as individual need or use for the proposition and the social context affect the manner in which something is known.

This movement to the known begins with a question, or inquiry that is a combination of that which is known and that which is unknown. Hence the formulation of the question(s), naming that which is unknown is essential. Similarly, the second step is to sort out and relate knowns and unknowns, what can be, or needs to be known, and how these might be known. This struggle requires exploring the knowns and unknowns, the conflicting data, and setting up the conditions for insight. Here solution patterns, or formula – the theories related to the particular data become useful, and can be good guides for reasonable conclusions. This process of moving to the known, is referred to as common sense knowing, a "*modest and secure undertaking… to understand things in their relation to us*" (Lonergan, 1992, p 232)

In brief summary, the work of *Insight* makes the case for a reliable method of the human mind developed from carefully examining the consciousness of the human knower. His theory of cognition employs a tripartite focus on experience, understanding and judgment, where humans routinely use multiple and different heuristics for aiding the transformation of the unknown to the known. It examines the creative, inquisitive conditions for an insight, the volitional, intertwined series of cognitive states that move the knower from experience and inquiry to understanding and judgment. Further, these heuristics are both individual, and communal, with the establishment of various canons, or patterns that are normatively socially and culturally located. Further, these heuristics or patterns of knowing are expected to be developed over time, as the need for different types of insights changes.

ENGINEERING INSIGHT

Lonergan's cognitional theory is proposed as a norm of intelligence, unique to humans; and sets up the possibility that patterns for engineering thinking may be established. Lonergan uses a set of six '*Canons of Empirical Method'* to illustrate his exploration – "insight into the nature of insight." These canons of selection, operations, relevance, parsimony, complete explanation and statistical residues are used illustrate how his cognitional theory maps to specific modes of thinking common to scientific practice. The Canon of Selection, for example is the notion that the inquirer is confined to insights into the data of sensible experience. This canon differs from that of operation, wherein the enquirer collects and systematizes from the insights of selection. These result in cumulative verification with the resulting refinement and accuracy of the lessons of selection. When working with well-understood data, desirable higher viewpoints are achieved by expanding, constructing, analyzing and constant checking (Lonergan, 1992, pp 91 – 99). While this 'canon of observation' is clearly a key component to engineering knowing, it would be incomplete to consider it as the whole.

Engineering purposefully addresses the "*final, material, instrumental, and efficient causality*" through the application of pragmatic values embodied in methods and directed by purpose to achieve the desired causality through the identification of human needs and desires, and the creation of suitable artifacts that meet human needs. Certainly these insights include those discipline-specific heuristics related to the development of effective artifacts. However, this understanding of 'engineering insight' includes discovering the complexities of the context(s) – where the human needs and desires are located, and drive the value proposition of the effort. It includes recognizing that these context(s) may only be known by the engineer through their exploration of the problem/opportunities with others.

Engineering, at its foundations is 'both' using the hard and soft sciences and mathematics 'and' pragmatic, and more than both: it is about generating and using knowledge for a purpose and with a method that is more than theory, more than descriptive: it is useful, and the usefulness is never ideal, but rather located within a context, and significantly social in its application. (Frezza, 2014). This concept is labeled a '*pragmatic theory*' of knowledge, which in Lonergan's terms might be described as an '*Engineering Design Canon'*. This distinction in knowledge generation is both individual and social; it affects the use of the knowledge, and shapes the manner in which it is generated (Frezza, Norqduest, & Moodey, 2013), and builds on the cannons of observation and statistical residues that Lonergan proposed. In a sense, the cognitional theory presented in *Insight* suggests a particular engineering insight that extends beyond Lonergan's Canons, and provides a unifying sense of engineering knowing that draws together many of the components of engineering philosophy present in the literature.

For example, the value of usefulness as a distinguishing factor (Frezza, 2014) is significant, and drives the engineering knowing process differently from that of the canon of operations alone. This suggests that engineering activities may best be viewed by a set of values (pragmatic use), which are necessarily located in a context, and exploring the context is part of the engineering activity. The role that context plays is significant, because from a knowledge perspective, context includes sociological expectations, domain-specific patterns and problem-specific knowledge that either, must be brought, learned or synthesized as part of the engineering activity. These are patterns of knowing, patterns for developing engineering insight. These patterns of knowing are embodied in the images derived from our senses, shared in the models and language of the design (Bucciarelli, 2003), and necessarily include patterns of questioning (Gause & Weinberg, 1999) and development of argument (Kallenberg, 2013) for the individual and collective understanding both of the problem and solution (Smithers, 1992). These are patterns of knowing which are necessarily heuristic and go beyond traditional patterns of science, art or applied science (Koen, 2013). A challenge to understanding these patterns of engineering knowing is distinguishing knowing from that of willing (Schmidt, 2013).

KNOWING AND WILLING

With the "*method of the human mind*," Lonergan offers a shared foundation for the varied methods of knowing employed by engineers. Each is a version of the basic underlying method of knowing, but tailored to fit particular materials and contexts. However, the unity Lonergan helps us discover in engineers' knowing may appear overshadowed by a more fundamental diversity between their knowing and their willing. One distinguishing viewpoint on engineering emphasizes willing above knowing. "*Engineering… seeks to know in order to make*." (Sich, 2014, p. 45) From this perspective, engineering is can be considered more a matter of art and skill in applying knowledge and, therefore, more of willing than of knowing. This viewpoint emphasizes a disjunction between volition and intellect, making choices instead of adopting beliefs, motives rather than reasons, deciding rather than judging, and being responsible more than being reasonable. Engineering in this context would appear a captive enterprise, subject to a variety of intellectual and social limits, which frequently place market and organizational needs above technical considerations, and as a result "*instrumental in nature*." (Schmidt, 2013, p. 107)

This instrumental perspective is consistent with others emphasizing the heuristic design procedures of engineers. (Koen, 2003) From this perspective, the same heuristics may lead to a variety of suitable designs and different heuristics to similar designs. The design procedure appears to be more a matter of art and will than of knowledge, with "*intentionality*" a better descriptor of the engineering process than "*rationality*." At its heart, designing in the face of constraints, legal restrictions, political considerations, and technical tradeoffs has "*no rigid and inerrant formula that will provide the 'proper' outcome"* for such designs. (Schmidt, 2013, p. 108) Design decisions are not deductive but inductive: thus from the instrumentalist perspective, engineers reach conclusions that are not certain, relying on tacit knowledge, and are more a matter of the artist's sense of fit than of science.

Although consistent with these and others perspectives, the instrumental perspective remains incomplete. Willing and knowing are part of a continuous process, and viewing an enterprise like engineering as either willing or knowing, (or more willing than knowing) ignores this continuity. The instrumental perspective that emphasizes willing is an important and challenging contribution to our understanding of engineering insight. It can be developed by drawing more fully on Lonergan's account of willing, as well as on his treatments of common sense, the modern understanding of science, and the importance of feelings and authenticity in deliberating and deciding on values. In this know*ing*-based approach to the philosophy of knowledge, Lonergan argues for more continuity between knowing and willing, for a greater contribution from common sense thinking, for the importance of feelings as sensitizing us to value, and for the fundamental importance of authenticity.

In *Insight* Lonergan argues that *"[m]an is not only a knower but also a doer; the same intelligent and rational consciousness grounds the doing as well as the knowing; and from that identity of consciousness there springs inevitably an exigence for self-consistency in knowing and doing*" (Lonergan B. , 1992, p. 622). This exigence for self-consistency leads Lonergan to reject a "*faculty psychology*" consisting of separate faculties of "*the intellect*," "*the judgment*," and "*the will*," Rather, there are interrelated operations of a unified mind. In this sense of "the will" not separate unto itself, but rather a part of a whole that focuses on authenticity (self-consistency) in decision-making: "*It is this highly complex business of authenticity and unauthenticity that has to replace the overly simple notion of will as arbitrary power. Arbitrariness is just another name for unauthenticity. To think of will as arbitrary power is to assume that authenticity never exists or occurs*" (Lonergan, 1973, pp 121 - 122). Hence for Lonergan, the authenticity at stake is the consistency between our knowing and our deciding.

A Authenticity in knowing and willing

Willing shows its continuity with knowing by situating the object of willing in a "*good of order*" wherein through our decisions we recognize not only a particular good, but also an increasingly complex good. In this view, simple acts of consumption, prompted by hunger or thirst are not true acts of willing. Such actions are more on the level of animal life. True willing requires reference to "*an intelligible good*," one in which "objects of appetite are subsumed or placed within some apprehension of a good of order." A meal is a particular good, while something like the "*Meals on Wheels*" program that serves the elderly establishes a complex good of order. It is in these various levels of the good of order that the authenticity of willing is found.

The will viewed in the context of order implies that logic has an important role to play in authentic willing. Lonergan argues that you cannot responsibly will an antecedent without willing the known consequent or choose the part while rejecting the whole or choose the conditioned while repudiating its condition (Lonergan, 1992, p 632). Authentic willing, viewed in the context of a good of order, flows from its "*intellectual antecedents*." These antecedents are identified as "*the sensitive flow, the practical insight, the process of reflection that lead to the decision*." (Lonergan B. , Collected Works, 1992, p. 632)

- *Sensitive flow* is the experience inquired into and consists of our various conscious sensations, imaginings, feelings, and bodily movements. Authenticity at this stage requires attentiveness, without which we would lack sufficient data to move on to an understanding of problems and possibilities.

- *Practical insight* reveals ways in which the world is subject to being altered. Practical insights are similar to factual ones in that both seek intelligible unities or correlations. However, factual insights address whether patterns are present and practical insights whether they might be made to be present. Engineering education teaches a variety of typical situations and transformations and engineers will normally search the data to see if standard patterns might fit or if new ones are discernable. Authenticity at this level requires intelligence – inquiry, insight, and apt formulation.

- *Reflection and judgment* is where we affirm or deny the existence or possibility of some ordering. For Lonergan, practical judgments are highly complex, dealing with the object of the act, our motives for it, its consistency with the accepted order or its contribution to improving that order, as well as with the intelligence and reasonableness present in the agent intending such an action. The last factor shifts attention from the action as object (rational consciousness) to the actor as subject (rational self-consciousness.) As with factual judgments, the norm for authenticity here is reasonableness.

These intellectual antecedants to willing are not entirely rational, but their authenticity is framed by logic and practical reason. At the root of the continuity and consistency between our knowing and willing is thus one's internal sense of the good, and our freedom to choose the good (*e.g.,* character/virtue). Authentic willing consistent with knowing flows from applying these antecedents, setting the stage responsible decisions. This analysis has important implications for engineering education, one of whose tasks it is to teach engineering virtues and, thus, authenticity.

B Willing and deciding

The fourth element in Lonergan's account of willing is decision, which puts an end to deliberation by consenting or declining to enact a course of action vetted by practical reflection. In the process of deciding, we put an end to deliberation by enacting or refusing to enact a course of action vetted by practical reflection. That a decision is needed to end practical reflection and to act may seem to lend support to the instrumental view that engineering is more about willing than knowing. However, Lonergan would disagree, comparing decisions to factual judgments and argues both "*are rational, for both deal with objects apprehended by insight, and both occur because of a reflective grasp of reasons*." (Lonergan B. , Collected Works, 1992, p. 636) Judging, he maintains, involves an "*unfolding of the detached and disinterested desire to know*," while rationality of decision-making "*emerges in the demand of the rationally conscious subject for consistency between his knowing and his deciding and doing.*" Rational decision-making is hardly just instrumental, rather it is ranked by its consistency with knowing.

A different challenge to the continuity of knowing and deciding is the argument that the "*staggering array of variables that influence what is ultimately constructed*" makes a deductive, purely rational decision atypical. (Schmidt, 2013) The multitude of variables in the context of engineering decision-making are similar to those forming the context in which common sense operates. Precisely because of the impossibility of perfect knowledge and unlimited time for deciding in everyday life, we develop various rules of thumb and examples to guide us and then rely on additional insights into the situation to determine which rules of thumb best apply to our present context. Lonergan would not see this as in any way non-rational. Similarly, in determining which engineering solution best fits the "*staggering array of variables*," insight is required and its adequacy can be assessed by reference to the data, integrated with heuristics both of inquiry and the state of the art, leading to individual and collective understanding of the problem and potential solutions. This is the heart of engineering insight.

Becoming an engineer requires transforming oneself through "*a laborious process to acquire mastery*" (Lonergan, 1992, p 621). That mastery involves a habitual willingness to move beyond recognition of problems and practical possibilities, and to move to effective acts of willing that transform the environment by realizing some good apprehended as part of an intelligible order. Thus, authentic willing is impossible apart from an intellectual grasp of order, as knowing and authentic willing are inseparable. In engineering knowing, this significantly implies the formation of, and formulation of a "*good of order*" that informs knowing and decision making. This perspective suggests that engineering knowing embodies a virtue of authenticity in the agent realized in the consistency of reasonableness. This assertion, while useful, still leaves open the question of what distinguishes engineering knowing from the various forms of common sense knowing.

DISTINGUISHING CHARACTERISTICS OF ENGINEERING KNOWING

In examining distinctions in engineering knowing, what are of interest are distinguishing characteristics that lead to engineering insight - the experiencing, understanding and judging typical of core engineering activity, where engineering insight is recorded and acted upon: design. "*Design*" in this context denotes both the content of a set of plans (as in "the design for a new airplane") and the process by which those plans are produced. In the latter meaning, it typically begins with questioning to understand the context of the problem or opportunity for which some new object is wanted. This inquiry typically involves tentative sketches of what is understood – and what has been observed and or committed to in some form of layout (or layouts), expressed in some language (abstract, natural, or visual) of the arrangement and dimensions (properties) of the object. These tentative layouts are both part of the '*experiencing*' of the engineering method, but also represent partial understandings which are then subject to judgment: checking of the candidate object by mathematical analysis or experimental test to judge the results, and lead to a decision. If judged insufficient, then the design is modified in ways to better achieve the goal. This is a process of refinement, subject to a rational understanding of the need for timeliness, precision, comprehensiveness, and/or completeness. Ultimately, the design effort is judged by its costs and results – the usefulness of the design and/or product. (Pitt, 2007; Vincente, 1990). Scientific and mathematical knowledge are used in design as means to an end, tools to approximate reality, to support analysis, insight and judgment and not an end in themselves. Distinguishing aspects of engineering knowing would include at least the following aspects:

- ***Intentional questioning***: design work always includes some social, economic, organizational, environmental, regulatory and even political context that requires inquiry into the nature of the problems and/or opportunities intended to be solved (Smithers, 1992). Consequently, questions that explore the requirements are fundamental to effective, reasonable design work. (Gause & Weinberg, 1999)
- ***Role of practical reasoning***: fundamentally design is about the application of practical reasoning (Kallenberg, 2013, p19) that is about reasoning to support action. In this context, it is similar to ethical reasoning, where details are essential to reasoning, and the relevance of details is not necessarily obvious
- ***Engineering use of math and science***: is primarily as a means to an end, and includes the realization that math and science (ideal/empirical) are only approximations of reality (Kallenberg, p. 19).
- ***Constructive***: From a linguistic or goal perspective, engineering knowing differs from other knowing in the goal: It is always future-focused, about how things ought to be. (Bucciarelli, 2003; Cross, 2007). Engineering knowing focuses on the description of a new object, system or process that did not but might exist.

- **Values and value claims**: Another area that distinguishes design includes the discussion on how the inherent values embedded into engineering design. This can be thought of as its 'ethical character.'

The immediate observation is that these characteristics of engineering knowing are not independently sufficient to distinguish engineering knowing from other types of knowing, but rather establish it as a hybrid or intermediate form drawing on both scientific and common sense styles of knowing.

IMPLICATIONS FOR ENGINEERING PEDAGOGY

Lonergan persuasively argues that there is a method of the human mind underlying all common sense and scientific knowing and that practical decisions are an extension of this method. Engineers employ different forms of common-sense reasoning to a greater extent than scientists and artists. Their work builds on their experience, and is intentional, rooted in problem/opportunity-based inquiry to expand the effectiveness of their experiencing. So in some sense the purpose of design education is not to create an artifact but rather to grow as an engineer. By virtue of the practical reasoning engineering students constantly and repeatedly devise satisfactory responses to context-dependent problems. This should be contrasted with the historical, socially-constructed view of engineering dominant in engineering education. If accepted, this implication strongly suggests that the focus of common or 'core' engineering should shift its common locus from applied technical or scientific knowledge to problem/opportunity-related inquiry coupled with practical reasoning and context-dependent problem solving. It significantly suggests that what we should call engineering is broader, and deeper in impact than what is identified by accrediting bodies whose guidelines are structured on the historical-social viewpoint.

Lonergan's examination of insight and this line of reasoning both suggest that there is a broader understanding of engineering as a way of thinking – encompassed in a discipline and set of activities that crosses national, accreditation, and institutional lines. For those leading engineering programs, particularly those that cover multiple engineering sub-disciplines, the implications are significant – Foundations in engineering go beyond discipline-specific norms and are rooted in norms inherent in the knowing process itself: attentiveness, intelligence, reasonableness, responsibly (Lonergan, 1973; Schmidt, 2013). In this sense, engineering fundamentals are thus neither rooted in math and science nor in art but in the mind itself.

The various engineering heuristics are derived from these norms. Advertence to the analogous character and common source of the heuristics may help the engineering educator trying to better optimize limited course or credit hours. It suggests a significant development of skills pertinent to both contextual and context-free methods of inquiry and effective design analysis. This should include foundations and practice with the argumentation and synthetic reasoning necessary for design, and the practical reasoning surrounding puzzle making and puzzle solving. For the engineering educator trying to better optimize limited course or credit hours, this suggests significant development of skills and affect surrounding contextual and context-free methods of inquiry, and effective design argumentation. (Frezza, 2014)

Thus, this analysis of engineering insight has several implications for engineering pedagogy, particularly related to attentiveness, intentionality, engineering virtues and the ethical character of engineering:

- **Attentiveness to Knowing**: Students should become aware of the operations of their own minds as they confront and solve engineering problems or as they think through classic design successes (and failures). Instructors can help them advert to the operations of experiencing, understanding, judging, and deliberating and deciding involved. Lonergan explains the great value of such an approach in *Insight*: "Thoroughly understand what it is to understand and not only will you understand the broad lines of all there is to be understood but also you will possess a fixed base, an invariant pattern, opening upon all further developments of understanding."
- **Intentionality Analysis**: Adverting to the underlying pattern of all knowing will help unify engineering pedagogy. One of its basic problems is the diversity of techniques used at different points in the engineering process. Sometimes the greatest rigor and precision is required, while at other times the "good enough" standard of common sense is sufficient. An intentionality analysis which adverts to the different ways the underlying method of the mind is applied can provide a much-needed unity (Lonergan, 1992, p 392).

- **Engineering Virtues**: Before engineering students can change their environment, they must change themselves. The advertence to operations of the mind and to the norms built into these operations will assist students in grasping and acquiring what might be termed "engineering virtues," habits of knowing and deciding consistent with Lonergan's transcendental precepts -- "*be attentive, be intelligent, be reasonable, be responsible*." (Lonergan B. J., 1973) These norms of knowing and deciding provide an index of one's authenticity and, as applied to engineering, of one's professional authenticity.
- **Ethical Character**: The approach to knowing presented above emphasizes the continuity between knowing and willing. Lonergan argues that we find within ourselves a demand for consistency between our knowing and our doing. This is due to the need to will something as part of an intelligible order. Thus, one cannot consistently will the part, the conditioned, or the antecedent while repudiating the whole, condition, or consequent (Lonergan, 1992, p 625). The intentionality analysis offered by Lonergan provides a way of illuminating the ethical character of engineering.

Engineering is about the application of practical reasoning, utilizing mathematics and science as a means, engaged in activities about how things ought to be - the constructive nature of designing (Cross, p. 24). Such a broad definition of engineering design resonates with, and extends work suggesting that there is significantly more to be learned in engineering that is not located within a particular discipline (Koen, 2003; Bucciarelli, 2003; Cross, 2007). Most centrally, this work suggests that there is a body of applicable work in philosophy of engineering that is central to design education. At the undergraduate level, where most engineering students select a sub-discipline to specialize in, this implies that undergraduate engineering programs should emphasize of a common core to engineering emphasizing design and including intelligently emphasizing design reasoning. This could be a significant departure from the mathematics and science coursework common to most current programs. Similarly, there is more opportunity for cross-disciplinary work that builds on, and reinforces the cognitive and affective aspects of ethical and design reasoning.

CONCLUSIONS

This work presents a very brief treatment of the philosophy of knowledge rooted in Bernard Lonergan's seminal work, *Insight*. Lonergan distinguishes an underlying method of the human mind that is the source of the more specialized methods employed in the empirical and applied sciences and in the various developments of common sense. The polymorphic character of human knowing, operating in such varied contexts, suggests using a pragmatic theory of knowledge as a lens for examining the nature of engineering design as activities of knowing and willing. In accounting for specialized methods of knowing, tailored to the varied needs of knowers and subject matters, Lonergan's approach offers a knowing-based approach with the flexibility needed for an epistemology of the many-sided activity of engineering. With his account of the basic method of the human mind underlying specialized methods, he also offers a basis for unifying the theory and pedagogy of engineering. Moreover, in carefully relating knowing to willing, Lonergan's work provides a basis for a conception of engineering that gives due recognition to its ethical character and to the need for engineering virtues.

This knowing-based view of engineering presents significant challenges for engineering educators. Over the mathematics- and science-dominant programs currently deployed, this re-definition of engineering focused on the development of '*engineering insight'* emphasizes the philosophy of design, provides the basis for a core, discipline-neutral approach to engineering, proposing attentiveness, intentionality, engineering virtues and character at the center of engineering education.

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Non Nova, Sed Nove Part I: John Macmurray and Engineering Education

Alan Cheville

Introduction: Why John Macmurray?

This paper focuses on the life and life's work of the rather obscure 20th century Scottish philosopher, John Macmurray, who while well-known by many modern religious thinkers, is not widely recognized in academic philosophy circles. Despite his relative obscurity and work in natural theology Macmurray's philosophy has great potential to inform reconceptions of engineering education. Macmurray was a systematic thinker who was interested in the broader application of philosophy to human society. He developed philosophy based on thought being secondary, and in service to, action much in the way that some claim engineering instantiates the discoveries of science.

To address the relevance of Macmurray's work, this paper explores Macmurray's life and outlines the major themes that emerge from one of his best known works, the two volume Gifford Lectures that represent his mature philosophy (Costello, 2002). This paper addresses only the first volume, *The Self as Agent*; the second will be addressed in a subsequent paper. In the Gifford lectures Macmurray lays out many of the major ideas that were his life's work, ideas that can better inform how we can educate engineers to face complex human challenges in the coming years. Two questions form the basis of this inquiry into Macmurray's work:

1) How does Macmurray's philosophical system align or conflict with the beliefs and values of engineering educators?
2) What actionable ideas can engineering educators draw from Macmurray's philosophy?

These questions are addressed follow a discussion of *The Self as Agent*. If one does believe engineers are aligned towards action, a close reading ofMacmurray indicates engineering education as practiced may be preparing students to serve as a means to someone else's end.

Brief Biography and Influences

John Macmurrray was born in Scotland just before the start of 20th Century into a devoutly Presbyterian family; this religion likely influenced his systematic approach to philosophy. As a young man Macmurray fought in the Great War where he served first in the medical corps and later on the front lines in a combat unit where he was severely wounded. Following the war his resulting disillusionment with religious and secular society led him to question traditional methods and approaches. While he remained deeply religious throughout his life, until his affiliation with the Society of Friends later in life he did not participate in organized religions. An introvert by nature, his deep friendships with many leading thinkers of his day strongly influenced his philosophy. These three elements—the base purpose of religion, the inhumanity of society, and friendship—were to form a very personal philosophy that had a strong influence on his professional work (Costello, 2002).

After the war, Macmurray completed his degree and served in multiple senior academic positions throughout his life including Oxford, University College London, and finally the University of Edinburgh in 1944 where he stayed until his retirement in 1958. He had a successful academic career, but did not publish in academic journals as much as he gave lectures, wrote books, and became a well-known and followed public figure through the first radio broadcasts on philosophy that he hosted for the BBC in the 1930's and early 1940's (Hunt, 2001). Throughout much of his life he was active politically in various aspects of the socialist and communist movements in Britain and an influential figure in many organizations from the Social Democrats to the Woodcraft Folk. Macmurray's activism arose from his belief that the political movements of his time—fascism, communism, and corporate capitalism—did not adequately take human worth into account and his politics and philosophy critiqued the organic and mechanistic values that underlie these belief systems.

It is difficult to classify Macmurray as a philosopher. His work has a strong spiritual component, yet is based on rational rather than revelational claims. His work is influenced both by the Christian religion but also by Kant and Marx. He is often classified with the diffuse philosophical movement known as personalism which focuses on the uniqueness and dignity of individuals (Williams & Bengtsson, 2014). He is also classified as a humanist and his major work clearly aligns with humanist views of human value and agency as well as a critical approach to religion. Others classify Macmurray as an idealist since his view of humanity maintains that idealism is necessary as the basis of correct action. Despite his relative obscurity in academic philosophy during his life there has recently been a Macmurray revival. In 1996 the British politician Tony Blair wrote the introduction to *The Personal World*, the first collection of Macmurray's selected works. A recent special issue of the *Oxford Review of Education* focused on Macmurray (Fielding, 2002), and the John Macmurray Fellowship ("The John MacMurray Fellowship Website," 2014) supports occasional conferences focusing on his work.

The Gifford Lectures

The most comprehensive of Macmurray's works are his Gifford Lectures given in 1952 and 1953 and published as *The Self as Agent* (1957) and *Persons in Relation* (1961). The Gifford Lectures, given at four Scottish schools—the universities of Edinburgh, Glasgow, St. Andrews and Aberdeen—are prestigious lectures on natural theology that have included a wide range of perspectives including those of William James, Alfred North Whitehead, Neils Bohr, Hanna Arendt, Karl Barth, and Carl Sagan. Macmurray's Gifford Lectures tie many threads of his work in philosophy together into one system and are the most comprehensive exposition of his philosophy (Costello, 2002). In his Gifford Lectures Macmurray makes a broad systematic foray to develop a new form of philosophy that spans much of human experience. The lectures broadly outline a tangent to rational, Western philosophy; Macmurray himself saw this work as an incomplete sketch rather than rigorous and complete. His hope was other would follow and further develop his thoughts. The tangent taken by Macmurray is the "form of the personal" which is distinguished from the form of logical (mechanical) or organic (romantic) thought addressed by many previous philosophers. By developing the form of the personal Macmurray sought to extend the boundaries of scientific and rational thought to encompass human endeavors such as art and faith so they could stand on the same footing as rational thought. Macmurray's philosophy addresses what forms a "good life" for the individual or the Greek ideal of *eudaemonia*, "human flourishing". For Macmurray many of the ills of Western society could be placed at the feet of a philosophy that emphasized the rational and thus did not adequately address all aspects of what it means to be human. The topic of *eudaemonia* is arguably of increasing importance to engineering educators; given the recent focus on branding engineering as a force for positive improvement in the world (Committee on Public Understanding of Engineering Messages, 2008) we should have a sense what should be improved and what "improvement" is. A prerequisite of claiming that engineers work toward human flourishing is for engineers to have a defensible philosophical position on *eudaemonia*. While the scope of Macmurray's philosophy is broad, his emphasis on action above thought provides new insights for engineering education as discussed subsequently.

In *The Self as Agent* Macmurray builds from a Western philosophical tradition that values individuals. The basis of this work is the claim that a philosophy of the personal must start with a view of a person as an agent capable of action that creates change in the world rather than a rational, disembodied mind. We are formed not from how we think, but from our actions that elicit a response both from the larger world and those who inhabit it. This is close to the philosophies of Martin Buber and Gabriel Marcel, both friends of Macmurray; of the three Macmurray tried to make sense of how the personal was to function as a philosophic system (Costello, 2002). Macmurray builds his philosophy of the personal from Kant's *Critiques* since he viewed the *Critiques* as the most adequate philosophy for tackling a range of problems related to resolving scientific, religious, and romantic thought. In the *Critiques* Kant attempted to resolve major challenges of his time: the challenge to traditional (religious) authority created by Descartes; the failure of mechanical philosophy to account for emotional and religious aspects of human life; and the organic elements of romanticism. Another reason Macmurray builds from Kant is that the *Critiques* form the basis for much subsequent Western philosophy and are thus a point to branch from in order to develop a philosophy that can guide a more humane society and tackle the challenges of the Contemporary period. From his historical vantage point between the two World Wars, where he observed the rise of Fascism, Macmurray claimed that organic philosophies, which view the individual as part of a larger social organism, undermine human autonomy and freedom.

Macmurray claims the keystone of Kant's Critical Philosophy is the "thing-in-itself" or tension between the noumenal (ideal, actual, inferred through thought from sensory input) and phenomenal (experienced, known through the senses) worlds. While the phenomenal world can be "known", the noumenal cannot since our perception of the world is skewed to some degree by our senses and schemata. Macmurray's two major criticisms of Kant are: 1) that by failing to align the theoretical (noumenal) and practical (phenomenal) aspects of reason Kant creates an unbridgeable dualism, and 2) because of this dualism Kant's philosophy fails to capture idealist aspects of human life. Macmurray viewed this dualism as a key issue for modern society and human freedom due to his perception of a widening contradiction between science and morality. This contradiction arises from Macmurray's claim that moral choice relies upon individual freedom since one must be free to act in a way that is right. However science and other mechanistic philosophies cannot guide such choice since they are ultimately deterministic, i.e. discover what already exists. Macmurray summarizes this tension as "*We can only know a determinate world; we can only act in an indeterminate world*." Although purely practical (phenomenal) reason provides the ability to act in the world, by itself practical reason inevitably leads to totalitarianism since a society that imagines "the greater good" will develop ever-better heuristics to achieve the envisioned end and work towards this goal both romantically and scientifically. This single-minded focus on an ideal drives society towards determinism and eventually totalitarianism. To allow individual freedom we must look to the noumenal world to determine "what is right to do", yet Kant gives us no path to resolve the phenomenal and noumenal; i.e. to account for our schemata in order to act in a way that is right. Macmurray saw the effects of this dualism acted out in the world in the rise of Nazi Germany.

Macmurray claims that the phenomenal-noumenal and subject-object dualism inherent to modern philosophies that emerged from Kant arise from the viewpoint of humans as rational, disembodied minds. To resolve this dualism Macmurray rejects Descartes' *cogito ergo sum* "I think therefore I am" as egocentric, focusing on solely the "I" rather than the "You". In the second volume of his Gifford Lectures Macmurray shows that the egocentric viewpoint does not sufficiently value personal relationships that can allow right action to be known. Macmurray was aware that from a historical perspective Descartes' philosophy replaced (religious) authority with rationality, or a systematic process of doubt, as the basis for belief. While Macmurray values this rationality he claims that the isolated, egotistical nature of a disembodied mind can doubt too much with the practical effect of eliminating potential good from the world. Macmurray conceives of humans as agents rather than thinkers, and the remainder of the *Self as Agent* develops a personal philosophy based on an isolated agent who has the ability to act to change the world as well as to understand how to act for the good.

Macmurray is aware that it is no small matter to break with a foundational idea of Western philosophy and *The Self as Agent* lays out how a philosophy based on action avoids the contradiction between viewing the self as a thinker, an idea which goes back at least as far as Plato, and the self as an agent. In brief, acting implies that one has *thought* about what action to take; thought is inherent to and implied by action. In this integrated view thought is the activity that determines true from false while action is the activity that determines right from wrong; there is no moral choice without action. Macmurray lays out four principles which guide the development of his philosophy of agency:

- The self exists only as an agent (the self-as-agent acts in the world and thus is a person with both physical and mental faculties).
- The self as subject is subsumed within the self as agent and is not separable (the self-as-subject is the rational, disembodied mind).
- The self as subject serves the self as agent (i.e. knowledge arises from reflection on action to serve future action).
- The subject and agent are necessary to each other (action and knowledge form a unity).

Macmurray was often criticized for his loose use of language (Costello, 2002). Here the term "agent" describes the person in the mode of action or engaging with the world while "subject" refers to the person in the mode of reflection, standing isolated from the world as a rational observer in Descartes' tradition. The agent engages with the world not just visually, a sense mode that implies disengaged observation, but through touch and feelings as well. I am more in the mode of subject when I grade, while I am in the mode of agent when I mentor. In other words, to act the agent must "push" against what exists, which Macmurray terms the "Other", see how it pushes back, and understand this resistance both rationally and emotionally. There is no subject-object duality in action; an agent in action is both subject and object since the Other always pushes back.

The Self as Agent next explores what it means to be simultaneously a subject and agent, doer and thinker. For Macmurray "I do" integrally includes "I think"; I must know the Other to be able to act upon it. Furthermore not any knowing or knowledge suffices to inform action. At the moment of acting the agent makes a choice, informed by the information available to them, which action will best achieve the outcomes the agent desires. To consistently act correctly requires the agent develop habits through practice; practice which allows one to act correctly is one goal of education. Developing habits for action is different than acquiring a defined body of knowledge. While knowledge *may* be useful to action, the value of any given knowledge is only determined through acting, thus making knowledge personal, i.e. knowing. Knowledge and action are distinguished temporally; action generates a past by actualizing a possibility and the knowing gained from this process illuminates possible future actions. Action only exists in the present since the past is determinate (and thus knowable) and the future is indeterminate; it is what we do now that matters. Thus both the usefulness of knowledge and development of habit are determined through action which makes possibility determinate. Through acting we directly confront questions of right and wrong that both refine our knowledge and develop habits; Macmurray points out that what is important is "How can I do what is right not how can I know what is right to do."

The actions of agents cause change, but change can also happen from a natural or organic event that is not caused by an agent. Thus it is important to distinguish the difference between change caused by an agent versus that caused by an event. Change stemming from the action of an agent is based upon reasons and intention while change that stems from events has a cause but lacks intention. The causes of change which lack intention can be explained by natural laws which operate independently of agents; Macmurray refers to natural laws that cause change as *continuants* since such processes do not change with time. As is well known in engineering and science, while natural laws have predictive capability their discovery requires careful abstraction and isolation from agents who can affect the outcomes. Agents, unlike continuants, are fully capable of changing their intention and can utilize natural laws to impact the future.

To be able to act effectively to bring about an intention an agent must utilize her knowledge of the Other. Although not discussed directly by MacMurray, action can be informed by what the agent herself knows through experience and what codified knowledge she can draw upon; here the term "knowledge" is used to cover both cases. Macmurray frames the relation between acting and knowledge through the continuous knowing-action cycle illustrated in Figure 1 below called "the rhythm of withdrawal and return". At the center this cycle are the Self (agent) and the Other the agent acts against; in *The Self as Agent* only a single agent is considered. The oval surrounding the self and other are events that take place sequentially in time. The upper center part of the cycle corresponds to acting and the lower part to knowing and/or knowledge (depending on how much the agent draws from her own or others' experience). The cycle plays out as follows: (1) Action begins when the agent has an *intention* to act against the other to achieve some desired outcome. The intention is to change the Other, and thus the future, in a way that is beneficial to the agent. This intention is derived from the agent's knowledge of the other and is forward looking into the future. (2) This intention results in an *anticipation* of the outcome of the action which may or may not be realized depending on the effectiveness of the action. Anticipation is not purely intellectual, but necessarily involves elements of feeling. (3) The agent then has a *choice* of how to perform the action which depends on factors such as intention, the anticipated outcomes, and what knowledge they have of ways to act. In the moment of pause following action the agent withdraws into the self, starting the reflective phase of the cycle. (4) The anticipation of the outcome determines how the agent pays *attention* to the effects of their action. Choice of attention is necessary since human beings are not omniscient; we must choose which outcomes of our actions to observe. (5) By focusing attention on some results of the action the agent constructs a *representation*—i.e. schema or theoretical model—of the relation between the intention and results of the action. Macmurray points out there are two ways to make accurate representations. The first is the path of science where specifics or particulars of the Other are ignored and the agent generalizes the result of the action such that the representation lacks unique features so it will apply to a broad class of Other. The other path MacMurray calls art because this representation focuses on particulars to create as detailed and accurate a representation of the specific Other at the moment that the action occurred and captures elements of emotion. (6) Regardless of the approach used, the agent's creation or refinement of a representation leads to *knowledge* which flips to the action part of the cycle, enables the agent to return to action, improve the means of his/her action, and thereby better fulfill his/her intention and realize the anticipated results.

The cycle of withdrawal and return captures the relationship between action and knowledge with several caveats. First, although the cycle is drawn with a Self and Other pole and reflecting and acting phases it is a unity and thus inseparable. Second, the starting point of the cycle is always action of some form. Third, action can be classified into both *practical activities* that are intended to modify the Other in some way and *theoretical activities* that are intended to modify the agent's representation of the other. "*A practical activity is one which intends a modification of the Other; a theoretical activity is one which intends a modification in the representation of the Other*." (MacMurray, 1961a, p. 178). Finally, the time spent in each aspect of this cycle of withdrawal and return is irrelevant. An agent may spend his/her life devoted to the theoretical activity of science with the result that his/her actions result in knowledge that allows for greater freedom of action whether or not that action is ever performed.

Macmurray next defines more precisely both what it means to act and what constitutes reflection. An act is defined as the realization of an intention and both the start and end of the act are defined through the agent's feelings. The start of an act is associated with a feeling of dissatisfaction which provides the rationale to act; the agent's valuation of this feeling determines both whether an action occurs and which action occurs. The agent's choice of action arises through prior reflection which allows a set of possibilities for action to be seen in the Other. Through a focus of attention the agent selects the most valued of these possibilities to act upon. For humans attention is selective so the choice to act eliminates, at least at a given time, other avenues of action. Thus valuations affect the choice of what to pay attention to, which in turn affects the cycle of Figure 1. Feeling also affects the end of the action since the agent will feel some level of satisfaction or dissatisfaction depending on whether or not the act accomplished the anticipated outcomes. How the agent acts upon this feeling determines the form or mode of reflection. Macmurray defines three modes of reflection: intellectual or scientific, emotional or artistic, and inter-personal or religious. In *The Self as Agent* Macmurray focuses on the intellectual and emotional modes; a discussion of the religious mode that describes interacting agents is left to *Persons in Relation*.

The intellectual/scientific mode occurs when the agent's attention is focused on ways to build a representation that can better inform subsequent action. By applying reason the agent follows the path of generalization towards science and draws broad conclusions about future action. This scientific mode generalizes to support subsequent action, and thus sees the world as a means to future action (ends). Although rational reflection is highly effective at informing how to better perform subsequent actions it can only inform whether the action is effective; emotional valuation of the act is needed to determine if it is the right thing to do to meet the desired ends. At the extreme of this mode the agent focuses solely on refining their representations, perhaps through experiment (a form of action). Macmurray identifies this extreme with pure science or reflection for its own sake; for example the predictive capability of science enables technology but cannot inform the moral use of technology. Alternatively the agent may pause at the end of action to emotionally gauge the satisfaction she feels; this is the emotional/artistic mode. The emotional mode of reflection focuses not on creating a general representation to support future action, but rather by creating an ideal representation of the moment after action that is accurate in all particulars. By capturing the Other in an emotional context that is drawn from particulars of the action the agent engages in art rather than science. Art allows us to fully experience the action of another. Since all three modes of reflection coexist, it is not reasonable to value one over the others unless the agent is willing to commit herself to action based on this valuation. In his claim that we act from emotions as well as reason Macmurray echoes William James (James, 1912).

Although the intellectual, emotional, and religious modes coexist, often within one agent, there are key differences. First, it is possible to go from the particular (emotional mode) to the general (rational mode) but the agent cannot with any accuracy go the other way; i.e. emotions can become rational observations, but reason cannot accurately create emotion after the fact. Second, it is not reasonable to claim that rational modes are objective while emotional modes are subjective since both originate within the mind of the agent. In other words humans both feel and think, and both our feelings and thoughts originate within us (based on the cycle shown in figure 1) so that at some level the objective and subjective are inseparable. A major claim of Macmurray's philosophy is that any duality is artificial.The intellectual/emotional/religious modes together define us as a person even if one mode may be dominant in some situations. Third, the exclusive reliance upon the rational mode has held back Western philosophy from being able to inform action in the world to achieve a greater good.

To conclude in *The Self as Agent* Macmurray addresses a key idea of his philosophy of the personal, "the world as one action". In essence the cycle of figure 1 is not series of disconnected actions and reflections, but is rather as a single, continuous, unfolding action of which the agent is but one part. Macmurray uses the discipline of history as an example to explain this concept by showing that history both generalizes (science) and particularizes (art). Like history both science and art are concerned with time. Science generalizes to create eternal means through knowledge while art particularizes to freeze an emotion (the moment of pause after action) eternally. History, like science, draws rational generalizations, but its focus is on human action on earth rather than on continuants. Historians, like artists, focus on particular moments in time. While these vignettes, like a scientist's experiments, inform an unfolding panorama, history does not produce theory since history's generalizations cannot reliably inform future action. Macmurray concludes that history is a synthetic discipline where the separate actions of many agents are recorded as a continuum that reflects societal rather than individual intentions. It is through these shared intentions that individuals become bound together in a society. Since the effectiveness of action depends upon knowledge (memory), history synthesizes actions and intentions into the memory of society; the accuracy of these representations informs how we act as a society. Macmurray considers how valid the generalizations of history are; i.e. can history only truthfully record the intentions of individual agents or can history synthesize to reveal societal intentions that involve multiple agents? To believe in the former is to see history as ferreting out coincidences between isolated agents while to believe in the latter is to accept that one's actions in the world contribute to a greater action. If we accept that we are bound together in action, then theoretically there is one history, that of mankind, and we may be involved in a single, greater action that Macmurray refers to through "the world as one action".

A singular agent asking what their part in the grander intention of the world is poses a metaphysical question. Metaphysics is not held in high repute in philosophy today (van Inwagen & Sullivan, 2014), nor was it in Macmurray's time when logical positivism was on the rise (Costello, 2002), since the answers it seeks cannot be confirmed. Macmurray points out that this disrepute stems from the emphasis that philosophy places on "I think", i.e. rational test and verification. However from the perspective of the "I do" metaphysical questions can be verified through action. Echoing pragmatists such as William James, Macmurray points out that acting as if one knew the answer to a metaphysical question has practical consequences which inform the cycle of withdrawal and return and thus affect the Other. Thus metaphysical questions matter to us since we would not seek to live a wholly rational (i.e. deterministic) world nor a world in which only the isolated mind exists since both deny the possibility of action and therefore change. The reality of how we actually live in the world does not reflect a philosophy based on "I think". Rather we live and act as if both our actions and their effect on others matter. In acting this way we determine a way of life that binds the world together in one action since my acts affect not only the Other but other agents as well. The reason Macmurray starts his philosophy with "I do" is that our actions matter and this irrevocably binds us to others. To act we must have some conception of the world we wish to exist and an intention to bring it about. Thus we must anticipate the ends of our actions and not merely the means. *The Self as Agent* focuses only on developing a philosophy of action, the means, and the end for which action should be turned is left to *Persons in Relation* and thus a subsequent paper.

Agency and Engineering Education

In *The Self as Agent* Macmurray lays out the first part of his philosophy of the personal by asserting the primacy of action rather than of thought, and that through action the subjective-objective dualities of Western philosophy can be resolved. Given that engineering is broadly defined as the application of science to meet human needs, a philosophy that emphasizes the practical over the theoretical should have some appeal to engineers.

Several implications for engineering education arise from *The Self as Agent*. In terms of the design of learning experiences, Macmurray's claim that knowing and acting are a unity implies that attempt to divide engineering along lines of theory versus practice are misplaced. The unity of knowledge and action is captured in the cycle of Figure 1, or in his own words:

> "*…the rationality of our conclusions does not depend alone upon the correctness of our thinking. It depends even more upon the propriety of the questions with which we concern ourselves. The primary and critical task is the discovery of the problem. If we ask the wrong question the logical correctness of our answer is of little consequence. There is of necessity an interplay, in all human activities, between theory and practice.*" (MacMurray, 1961b)

Engineering educators will recognize several research-based practices in Macmurray's cycle of withdrawal and return such as the need for multiple representations (Moore, Miller, Lesh, Stohlmann, & Kim, 2013) and the importance of reflection. Macmurray's description of how the agent's intention and anticipation of outcomes forces a choice of attention on some aspects of the action is commonly seen when students first encounter a design challenge. While expert designers consider multiple scenarios before making design decisions students (novices) typically focus their attention, limiting the design space (Atman & Bursic, 1998).

There are also implications for engineering education that are not commonly reflected in practice. How students practice the cycle of withdrawal and return determines whether they develop habits that enable them to act in a way that is right. Here the term *right* means with moral purpose while *correct* denotes that representations and knowledge conform to verifiable truth. Since correct knowledge is used for action, and action determines what is right and wrong then ethics should be integral, not secondary, to learning. Macmurray's insights on the centrality of ethics are highly relevant for a discipline like engineering education that consciously or not empowers individuals to act as change agents in the world; as Norm Augustine points out the actions of engineers have consequences (Augustine, 2002).

Engineering educators may also wish to consider the moment of pause where action turns to reflection in Figure 1. Macmurray claims that not only what we learn but how we act in the future depends upon this moment since the focus of agent's attention at the moment of pause impacts how representations are developed and thus what actions will be valued in the future. In a very real sense this steers a student's path. If the agent's actions are to be right as well as correct, successfully navigating the turning point requires that the agent learns to correctly judge their emotional reaction as well as engage in rational analysis. Thus Macmurray's philosophy suggests that engineering educators should develop ways to help students reflect on their emotions and also learn how to address negative emotional reactions. Many works on retention in engineering programs speak of a building emotional crisis before one trigger event causes the student to leave (Meyer & Marx, 2014; Seymour & Hewitt, 1994). *The Self as Agent* suggests that scientific and artistic modes of representation, as well as the inter-personal mode developed in *Persons in Relation*, are needed if the individual is to develop moral habits and the capacity to determine the ends their actions will serve. While not stated explicitly, the philosophy of the personal implies that a person who possesses only rational modes of reflection can unwittingly become an instrument of tyranny. While there has recently been a STEM to STEAM movement to incorporate art in STEM (Robelen, 2011) the published focus is to enhance creativity for economic development rather than developing the capacity for emotional reflection to develop capacity for moral action. What is said of students can also be claimed for engineering education more broadly. Researchers and practitioners must not similarly fall prey to a fully rational approach lest engineering education become fully instrumentalist. Macmurray makes the point eloquently in *Learning to be Human* (Macmurray, 1958):

> *"The attempt to turn would-be teachers into technicians by teaching them classroom tricks is as stupid as it is ineffective…Here, I believe, is the greatest threat to education in our own*

society. We are becoming more and more technically minded: gradually we are falling victims to the illusion that all problems can be solved by proper organization: that when we fail it is because we are doing the job in the wrong way, and that all that is needed is the "know-how". To think thus in education is to pervert education. It is not an engineering job. It is personal and human."

It is an open question how the capacity for multiple modes of reflection should be developed, but a broad interpretation of Macmurray implies that moral development requires sufficient agency (autonomy) that one's choices and actions matter. Engineering curricula tend to be highly constrained, however, limiting student choice. To develop the capacity for agency engineering educators should introduce more student autonomy in curricular pathways, not just within an assignment or course. Such autonomy would not only support moral development but allow students to pose and answer metaphysical questions. While such questions are not directly addressed in engineering curricula, they have deep meaning for students who are still discovering their path in life.

Finally Macmurray's view of the world as one action suggests several ways to reconceptualize engineering education. The one action viewpoint implies strong interconnection, or viewing the world as a system. From this perspective as the world and humans become more reliant on technology the importance of engineers' actions increases as does the need for engineering students to obtain a more liberal education (MacMurray, 2012) that encompasses societal and human concerns; this is not a new thought in engineering education (Mann, 1918). The one action perspective also implies that we should teach students not only how to analyze problems using engineering decomposition, but also how to undertake a holistic, synthetic analysis of their solution from emotional and inter-personal modes of representation. While we typically train students to perform rational analyses, Macmurray suggests that possessing only a scientific view of the world limits the agent to serve as a means to someone else's end rather than working towards their own ends. The question then becomes how can we help students envision the ends towards which they will choose to work? How we envision a worthwhile end, how we define the common good, is a question Macmurray addresses in his second set of Gifford Lectures.

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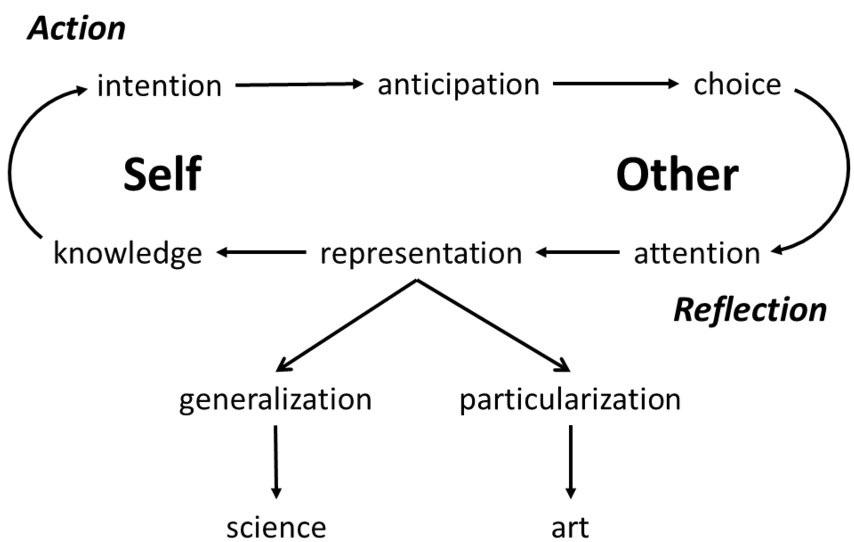

Figure 1: Macmurray's "Cycle of Withdrawal and Return" that takes place sequentially over time.